IMPLEMENTATION OF VEHICLE STOPPING LOGIC IN THE INDO-SWEDISH ROAD TRAFFIC SIMULATION MODEL

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IMPLEMENTATION OF VEHICLE STOPPING LOGIC IN THE INDO-SWEDISH ROAD TRAFFIC SIMULATION MODEL

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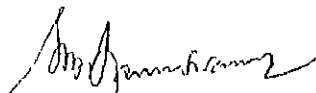SREE GURU RAGHAVENDRAYA NAMAHA

DEDICATED
TO
MY BELOVED PARENTS
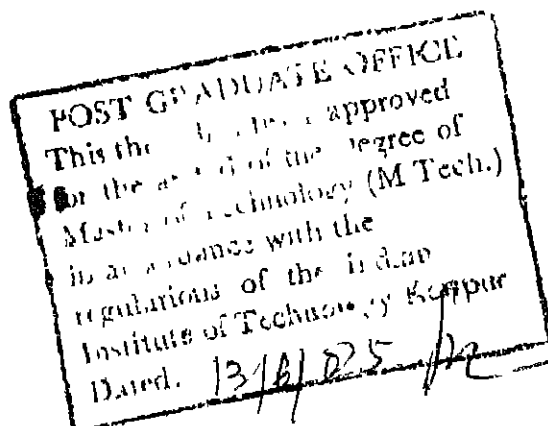
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CERTIFICATE

This is to certify that the thesis entitled
'Implementation of Vehicle Stopping Logic in the Indo-Swedish
Road Traffic Simulation Model' submitted by Mr.N.N. Prasad,
in partial fulfilment of the requirements for the degree of
Master of Technology of the Indian Institute of Technology,
Kanpur, is a record of bonafide work carried out by him under
my supervision and guidance. The work embodied in this thesis
has not been submitted else where for a degree.

May, 1985

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ABSTRACT

The traffic engineers have used the tool of modelling to understand and analyse the complex phenomenon of traffic. Analytical and simulation models have been used quite extensively for the above purpose. These models have aided in establishing warrants for transportation facility improvements.

In the above models all aspects of movement of vehicles excepting, stoppages of vehicles on road especially prevalent on Indian highways have been considered. The vehicular stoppages near narrow bridges, near road repairing spots and near signalized intersections and near random bus stops in rural highways are some of the examples which require development of adequate modelling to study the complete traffic movement behaviour.

In this study an attempt has been made to incorporate the vehicular stoppages near signals in the 'Indo-Swedish Road Traffic Simulation Model' developed at I.I.T. Kanpur in collaboration with Swedish National Road and Traffic Research Institute. The effect of such stoppages on the other vehicles is queue formulation is also modelled. In 'Indo-Swedish Road Traffic Simulation Model' the vehicles are moved depending on road interaction and vehicular interactions and behaviour of drivers. In this thesis the interaction of vehicles with signals when they encounter it is incorporated. The applications of this modelling approach to vehicular stoppages are explored and suggestions to implement the applications are briefly given.

CHAPTER I

INTRODUCTION

1.1 HIGHWAY TRAFFIC MODELS

The traffic flow process on streets and highways is
a complex phenomenon. The behaviour of vehicles along a road is
either described by a set of mathematical equations or by
heuristic methods, in which there are facilities to represent
the stochastic decision of each driver. Such representation
is called highway traffic model.

Traffic flow modelling enables better understanding
of the phenomenon of vehicular movements. These models should
be helpful for engineers in establishing standards for road
improvements which ensures safety, easy operations of vehicles
on roads and economy.

The traffic models are of two types. A set of
mathematical equations, used for solution of traffic problems are
called Analytical models. The other approach is to model the
traffic flow logic on a computer which not only includes a set
of equations governing the vehicle movement but also stochastic
decisions of drivers which are known as simulation models.

1.2 A REVIEW OF LITERATURE

1.2.1 Analytical Models

Empirical work on lengths of road is associated largely
with Wardrop [30] and Norman [19] . These studies are

particularly concerned with the relation of traffic speed
to the volume of traffic and to the width of road. In some
respects these relations are fairly precisely known, but
in others, such as the effects of traffic composition and
of varying proportion of oncoming traffic they are less
understood. Estimates are also available for the effect of
such factors as parked vehicles, pedestrains and grades.
Following on from the empirical determination of the relation
between mean traffic speed and flow or density is the theory
mainly associated with Lighthill and Whitham [13]. Traffic
is regarded as a fluid and certain results about the pro-
pagations of 'waves' and 'shock waves' have been obtained.
Lighthill and Whitham [13] used the mechanics of compressible
fluids to explain the flow of traffic on long crowded roads
on a single lane. A functional relationship between flow
and concentration for traffic was postulated,and from this
a theory of the propagation of changes in traffic distribution
is deduced. They called the relationship between flow and
concentration as the fundamental diagram of road traffic as
shown in Fig. 1.1. This work of Lighthill and Whitham [13]
is the first paper to appear in the literature using the
methods of fluid dynamics to explain phenomena that had
previously been observed in road traffic.

The above relationship holds good as long as a
two lane road experiences very high volumes in both the
directions. It has not yet been studied as to how this
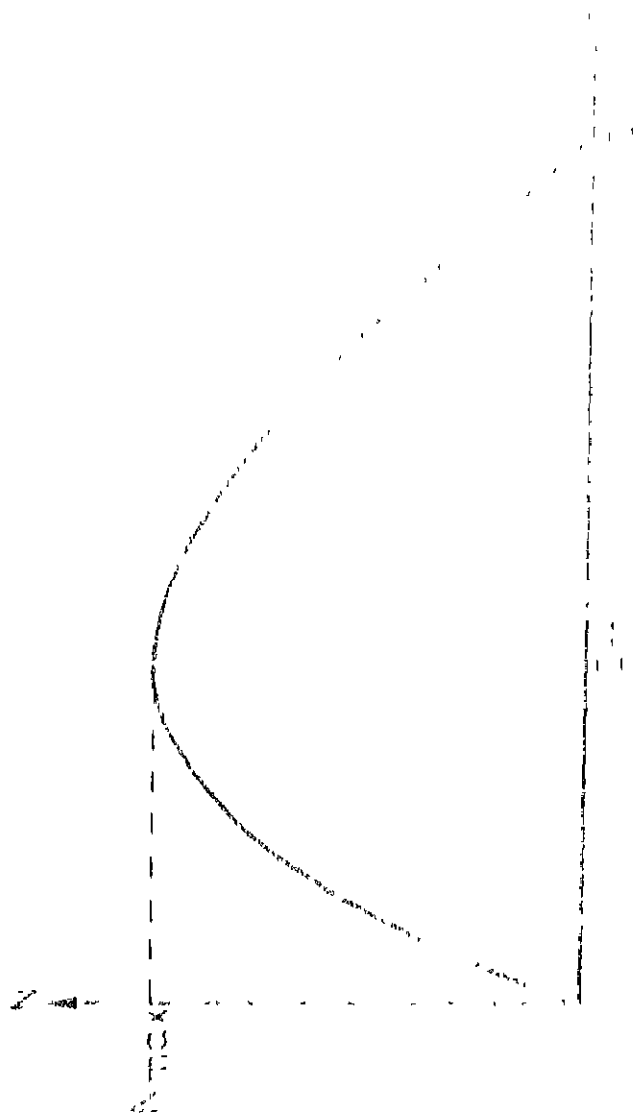
Fig.11

relationship will be affected when frequent overtakings
are prevalent under low to medium flow conditions. It seems
the complex nature of road traffic violates the continuity
assumption required in the model. Also, this theory does
not take account of the properties of individual vehicles
and therefore it cannot be expected to explain traffic behaviour
in any detail.

which

Of other theories/deduce the properties of a traffic
stream from the behaviour of the individual vehicles of which
it is composed are those due to Schuhl [25] and Kometani[12].
Quoting from Haight [9], who gives a brief general survey
of the literature on traffic theory 'Schuhl for examples,consi-
ders a two lane road in which the sole constraint to free
speed (the distribution of which he assumes to be known) is
the passing maneuver. For most of his work, Schuhl[25]
confines himself to averages-although he does allow negative
exponential gaps in the oncoming traffic. In particular he
assumes that cars in the same directions are overtaken at free
speed and at equally spaced intervals.'

'The most detailed analysis of the geometry of the
passing Maneuver of which I am aware is that of Kometani.
Two and three lane highways are considered with different
poisson streams in each lane. The distribution of free speeds
assumed to be discrete, as are the units of time. Assuming
values for several constants such as headway, time to pass etc.,
Kometani obtains a formula for the probability of n vehicles,

$n = 1, 2, \ldots$, being passed at a time'.

The major criticism of the above two papers are that they suffer from the disadvantage that the mathematical analysis given is not exact in that various approximations and simplifying assumptions have to be made. Exact analysis of these models would be very difficult, so it is not easy to extend their results.

Tanner [28] presented a theoritical formula for the average speed achieved over a long journey by a vehicle. Except for the vehicle whose behaviour is studied, other vehicles in each direction are assumed to travel at the same speed, and are spaced at random, but with a certain minimum distance between vehicles. The vehicle being studied wishes to travel faster than other vehicles. When it overtakes it must pass the whole of a bunch of vehicles at minimum spacing in a single maneuver it overtakes without delay if there is a sufficient gap in the opposing traffic. If delay occurs than a greater gap in the opposing stream is required to allow for time lost in accelarating. An important feature of the results obtained by Tanner is that when the traffic flows, increase beyond a certain level, appreciably below the theoritical capacity of the road the fast vehicle cannot maintain a higher average speed than that of the other vehicles. The whole time is spent waiting for opportunities to overtake, and the average wait per overtaking becomes very large.

Miller[14] proposed that on roads vehicles which are uninterrupted by traffic signals, intersections, etc. vehicles should be considered as travelling in random queues by which he means that the intervals between the tail of one queue and the head of the next follow the exponential distribution. Criteria based on headways and relative velocities are developed to determine when a vehicle is said to be under queue condition. Miller's random queues model appears very much more realistic as a representation of road traffic witnessed on two lane highways. If the road has both straight and winding sections, or narrow and wide sections, then the overtakings will all occur on the same part of the road and just down stream from this wider or straighter section, the queues of vehicles will themselves occur in bunches.

Carter and Palaniswamy [4] and Palaniswamy[20] have proposed a markov model to describe the traffic flow fundamental diagram in terms of state variants. After verifying the traffic flow process as a Markov process the authors have attempted to use dynamic programming concepts along with Markovian model for the on line control of traffic flow in the Baltimore Harbour Tunnel. The formalism was found to be quite satisfactory for evaluating control policies to improve the traffic flow in capacity restricted facilities.

1.2.2 Simulation Models

In recent years, a number of traffic simulation models have been developed for two lane roads. These models describe

the behaviour of traffic stream by considering in detail the behaviour of individual vehicles as they move over the specified section of the road. They are briefly reviewed here.

Shumate and Dirkson [26] model uses a Poisson distribution.for headways and a normal distribution of desired speeds. For overtaking maneuvre, 'valour' factor,which gives the probability of driver accepting a risk, is used. The model uses SIMCAR Language.

Paul Warnshuis [21] developed a simulation model in which drivers are always assumed to accept an overtaking gap if it allows sufficient safety margin. The results of two different desired speed distributions show that the speed distribution is not critically important.

in U.S.A.
Janoff and Cassel [11] model developed/forms the basis for North Carolina State University model. This model was primarily concerned with evaluating the safety benefits of remedial passing aids.

NCSU Model: This model [18] was developed at North Carolina State University (NCSU). The model relates the throughput of a section of road to the volume and composition of traffic entering the section. There are three stochastic inputs to the model, namely desired speed of the vehicles, headway distributions and overtaking behaviour when any given gap has a probability of being accepted or rejected. The simulation process is time based. The main drawbacks of the model are:- (i) the input speed and desired speed in the test section are assumed to be identical and (ii) no account is taken of horizontal curvature.

Taylor, Miller and Ogden [29] model is used to establish warrants for provision of crawler lanes on uphill grades. Downgrade traffic stream was not modelled as no overtaking was permitted.

Stock and May [27] model represents only one direction of traffic flow in microscopic detail, whereas oncoming stream is modelled as distribution of gaps moving at uniform speed. Only cars are permitted to overtake according to an empirical gap acceptance distribution and in favourable traffic conditions. Speeds are not varied with road geometry.

Indo-Swedish Model [10] is quite comprehensive and based on large scale data collection about overtaking behaviour and speed distributions. All types of overtaking maneuvres have been considered. The desired speed is related to road width, horizontal curvature, speed limit and gradient. The roadway is divided into homogeneous sections. Traffic is divided into four classes which consists of cars, trucks/buses, slow/ moving vehicles and motor cycle/scooter. The scanning is event oriented. The model is fully validated. The main drawback of the model is the amount of field work required as input. The model requires as input the observed speed and headway distributions.

MRI Model [16]: This model was developed by St.John and Kobett at Midwest Research Institute (MRI) under the National Cooperative Highway Research programme. The major objective of this study was to model and simulate traffic

flow on a two lane highway so as to determine the performance
capabilities of vehicles, to determine equivalency factors for
low performance vehicles, and to determine the role that per-
formance and size play in traffic instabilities, accidents and
loss of capacity. The entering time headways are based on
Schuhl's distributions. The distribution of desired speeds
in horizontal curves is related to curve geometrics. The
probabilities of accepting an overtaking opportunity are
related to speed of the leading vehicle and to passing
opportunity distance. The computer simulation was also used
to test the effects of vehicle dimensions and effects of
changes in percent no passing facility. The traffic behaviour
has also been evaluated for over width vehicles like mobile
home and modular house loads with widths of 3.6 and 4.2 metres.

1.2.3 Signalized Intersection Models

These traffic model have special isolated aim of
finding the effects of traffic on vehicles movement, such
as delay and queue lengths . A few of these models are
briefly reviewed below.

An example of simulation model is described by Daniel
and Huber [6] for signalised intersection. This model simula-
tes only for straight moving vehicles and for fixed time
signals. The model does not consider the vehicle movement
sequence either before they enter the intersection or after
they are processed through the intersection, but they are
generated and inserted into the queue . Then they are

discharged from the signal queue according to Greenshields [8] starting delay values which are given in Table 1.1.

TABLE 1.1: GREENSHIELDS STARTING DELAY FOR DISCHARGING VEHICLES FROM QUEUE HEAD

Position in Queue at Start of Green(M)	Time from start of Green until arrival at entrance of the intersection(in secs.)
1	3.8
2	6.9
3	9.6
4	12.6
5	14.2
6	14.2+2.1(M-5)

Various figures of merit used are, individual vehicle delays, maximum delays, average delay over all vehicles, average delay category wise, degree of saturation, load factor and maximum queue length.

Lewis and Michael [23] developed a simulation model to obtain volume warrants for intersection control. In this model they simulated a four legged intersection with fixed time signals. Delay was used as the figure of merit to obtain volume warrants. The vehicles were processed at the intersection using a car following model. They used the concept of release points to calculate vehicular delay.

Satyanarayana Reddy [24] developed a simulation model for signalized intersection for mixed vehicular traffic. Vehicles were not moved but discharged from the queue head into which vehicles were entered on generation, using observed starting delay in the field. The starting delay used were different for four wheelers and two wheelers. The starting delay used are as shown below.

TABLE 1.2 :   STARTING DELAYS FOR FOUR WHEELERS IN INDIA

Serial number of vehicle	Starting delay
FIRST	4 seconds
SECOND	8 seconds
THIRD	11 seconds
FOURTH	14 seconds
FIFTH	16 seconds
SIXTH	18 seconds
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----	-----
----	-----

TABLE 1.3 : STARTING DELAYS FOR TWO WHEELERS IN INDIA

Starting delays in seconds	Number of vehicles entering the intersections		
	Scooters	Rickshaws	Bicycles
3	5	4	9
8	8	8	17
13	11	12	25
18	14	16	33
23	17	20	41
28	20	24	49
-	-	-	-
-	-	-	-

Since the model did not move the vehicles it could not consider the effects of road quality and width in vehicular movement. Deceleration and acceleration of vehicles at intersections are not considered. The release points taken for delay calculation is arbitrary . Queue concept adopted near the signals also seems to be not correct.

It is seen from a cursory survey of literature that analytical and simulation models did not take into consideration at times vehicles do stop on roads for one reason or the other. In intersection models many/have taken indirect appro-
ach by assuming starting delays thus circumscribing the need for vehicular movement which includes stopping.

1.3 PRESENT WORK

Traffic flow on open roads was modelled with the assumption that vehicles are uninturrupted by signals at intersections, narrcw bridges, random busstops and any such other situations. This assumption is relaxed by introducing stopping logic required,not only at intersection but for many other situationsprevailing in Indian traffic. The vehicle movement sequence in terms of acceleration, deceleration and stoppage conditions are modelled in an attempt to impart more realism.

The effect on the other vehicles when a vehicle stops infront of them is either to pass it if no overtaking restriction is there or to stop behind it forming a queue. This situation is captured by building a queuing model.

The usefulness of a model with the capabilities of depicting acceleration, deceleration and stoppages in traffic movements has significant potential as an analysis tool for design and operation of the traffic facilities. The application of the present model has been explored and suggestions for implementation of them are given.

1.4 ORGANISATION OF THESIS

In this chapter a detailed description of traffic models with brief survey of different traffic models was given.

The following chapter discusses the simulation approach to the analysis of traffic engineering related problems. Several

simulation languages available is discussed with emphasis on language SIMULA-67, the one which has been used in this thesis.

The third chapter describes methodology followed in developing the vehicle stopping logic as well as their sequence of movement and description of the Indo Swedish Road Traffic Simulation Model (ISRTSM) in wchih the stopping logic capsuled, is given.

Penultimate chapter lists the input and output of the model.

Description of the results obtained from the model and scope for further research are outlined in the final chapter.

The four appendicies contains, the description of important procedures of ISRTSM, the flow chart of the present work, list of new procedures added and procedures changed in ISRTSM for present work and event file details.

CHAPTER II

COMPUTER SIMULATION APPROACH

2.1 WHY SIMULATE?

The major problem with the analytical models is that as the level of detail in the data is increased, it becomes more difficult to formulate equations-let alone solve them. Greater the number of input variables to be included, the more each will have to be approximated and generalised. If conditions at a given site are described only in generalised and compact form, then it is unlikely that the model can differentiate between before and after conditions relating to some small improvement.

Unless a fine level of detail can be input, the resulting information is only of limited value. So fully comprehensive analytical model is not a feasible proposition. Traffic flow modelling for Indian conditions is quite complex because of its
/nature heterogeneous consisting of different types of vehicle, in terms of speeds and physical dimensions. Also each maneuver made by a driver results from a decision sequence which is defined by variables having large random components. It is difficult to produce a realistic analytical traffic model for even homogeneous traffic. Hence the use of simulation methods for traffic flow analysis is natural and expected to play a significant role in solving problems related to design and operation of traffic facilities.

2.2 WHAT IS SIMULATION?

Digital computer simulation may be defined as 'a numerical technique for conducting experiments with certain types of mathematical models which describe the behaviour of a complex system on a digital computer over an extended periods of time' (Naylor, [17]). Simulation serves different functions in system analysis and design. They include

(1) Aids in problem formulation,

(2) Gives insight into the sensitivity of design to wide ranges of parameters,

(3) Guidance in predicting system performance,

(4) It is useful to validate the component models,

(5) Data can be generated and used to study the transient and steady state characteristic of the system (Reitman, [22]).

There are generally a number of steps in simulation of an engineering system. Though the details may vary from time to time, a number of steps are common to several simulation studies. Figure 2.1 is the representation of the various steps of simulation (Naylor, [17]).

(I) Formulation of Problem: The problem is formulated in analytic terms. It includes the identification of the system and its environment. Constraints of the system are also to be identified.
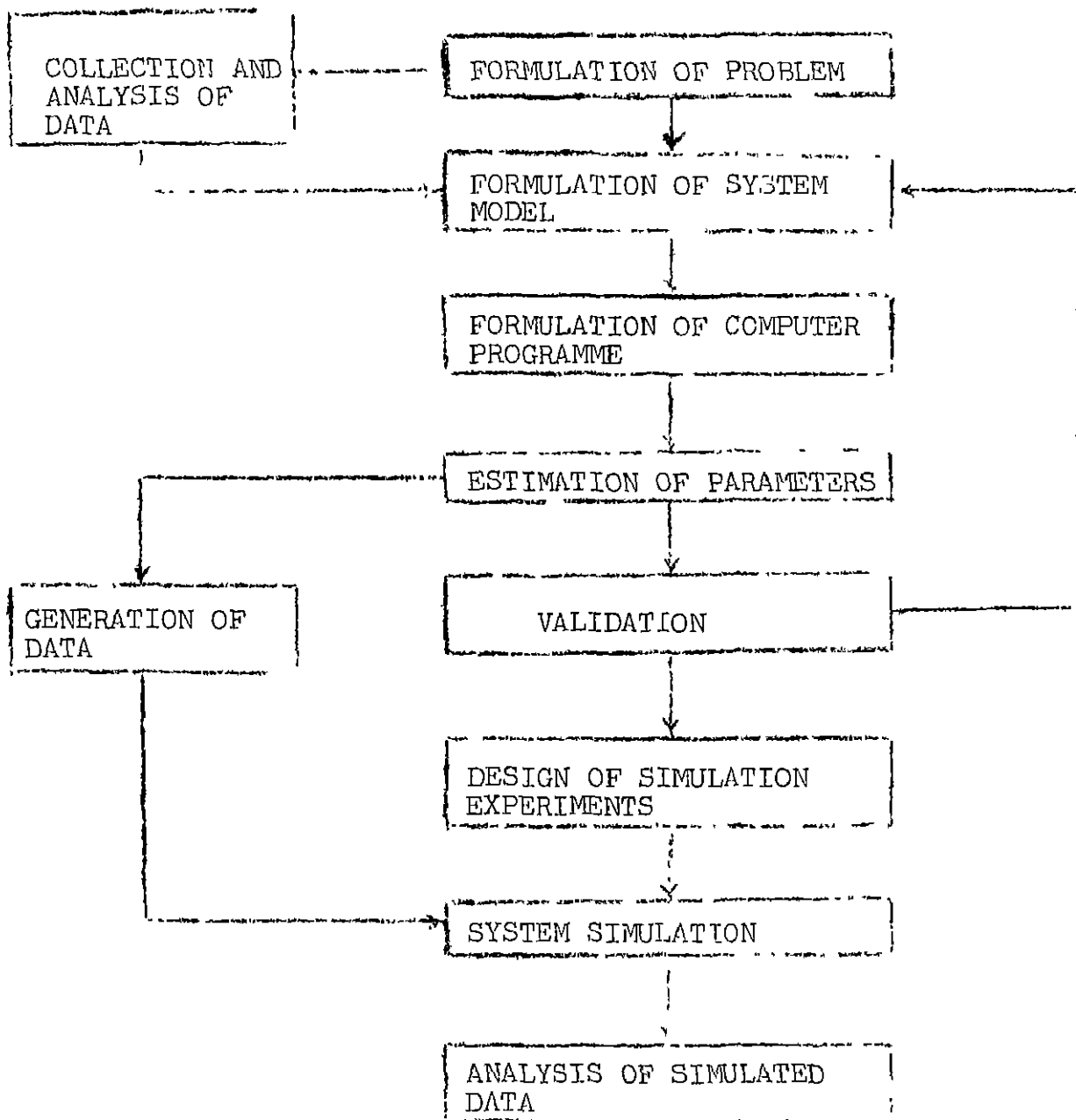
FIG. 2.1 : FLOW CHART FOR SIMULATION

(II)   Collection of data: Historical and experimental data
           concerning socioeconomic, engineering and other factors
           are collected and analysed.

(III)   Formulation of the system model: Based on experience,
           available knowledge and information, a system model is
           formulated to represent the components of the system,
           their parameters and behaviour and their relationships,
           the nature of the inputs to the system, throughputs,
           and outputs.

(IV)   Formulation of a computer programme: The formulation of
           a computer programme for the purpose of conducting
           simulation experiments with a model of a complex system
           requires special considerations to the following three
           activities (i) computer programme, (ii) data input and
           starting conditions and (iii) data generation.

(V)   Estimation of parameters: Parameters of the systems are
           estimated using historical and/or experimental data.

(VI)   Validation: The assumed mathematical model for the
           system is a simple approximation to a more complex reality.
           It is necessary to validate the assumed system model in
           order that the mathematical model is a reasonable appro-
           ximation to reality. Validation involves the definition
           of reality and a reasonable approximation to it. Generally
           validation is done on the basis of comparision between
           the actual recorded output and the output from

simulation model for corresponding inputs. In case
the model is considered to be unsatisfactory, it is
necessary to modify the model suitably in order that
estimated output from the model agrees with the
observed record.

(VII) Design of simulation experiments: Simulation may have to
be done for analysis and optimisation of complex systems
under different conditions of system inputs and outputs
and values of design variables, if any. The values of
these variables are generally to be sampled. Hence it
may be necessary to select factor levels and combina-
tion of factors and the order of experimentation. It
is also necessary to ensure that sampling errors are
within bounds.

(VIII) System simulation: The system is simulated under
different conditions as per the experimental design.
When random process are involved it may be necessary
to generate and use data concerning such variables.

(IX) Analysis of simulated data: Results from simulation are
analysed to determine the characteristics of various
components of the process, their significance and inter-
dependence. A near optimal design may be obtained in
appropriate cases.

2.3 SIMULATION LANGUAGES: (Mitrani [15])

One does not really need a simulation language in order to simulate. Any general purpose programming language can be used, with a greater or lesser degree of effort. What the simulation languages aim to do is to make life easier for the programmer by including some of the standard simulator components as language primative. The facilities that a good simulation language should provide fall into five broad categories: They are

A. Entity manipulation: Creating new entities, destroying old ones, placing entities into, and removing them from, ordered and unordered sets (st cks,queues etc.).

B. Time and event manipulation: Maintaining a clock and an event list, and executing the scheduling operations.

C. Random numbers: Sequences of numbers that appear to behave like independent and identically distributed random variables. Various discrete and continious distributions should be provided, as well as the ability to both reproduce and change the sequence between different runs of the same program.

D. Collection of statistics: Data that can be used to obtain means, variances, frequency- histograms and other quantities of interest. The collection may extend over entire simulation runs, or it may be restricted to seperate portions of them.

E.   Numerical computation : The ability to implement

        various numerical algorithms is required, e.g., in

        the statistical analysis of simulation output and in

        the construction of special random number generators.

In addition, a good simulation language should posses all those

qualities that are desirable in any programming language, such

as power, flexibility, simplicity, ease of use, readability,

modularity, efficiency of computation, run time efficiency,

good diagnostics etc. Some of the popular simulation languages

are SIMSCRIPT, GPSS and SIMULA.

2.4 SIMULA

        Although originally intended as a special purpose

simulation language, SIMULA is now a very powerful general

purpose language (Dhal & Nygaard [5], Bitwistle et.al.[1]),

structure of SIMULA can be loosely described by the following

pyramid.

```
          ┌─────────────────────────┐
          │ Class SIMULATION        │
        ┌─┴─────────────────────────┴─┐
        │      Class SIMSET           │
      ┌─┴─────────────────────────────┴─┐
      │      The 'class' Concept         │
    ┌─┴───────────────────────────────────┴─┐
    │              ALGOL 60                  │
    └────────────────────────────────────────┘
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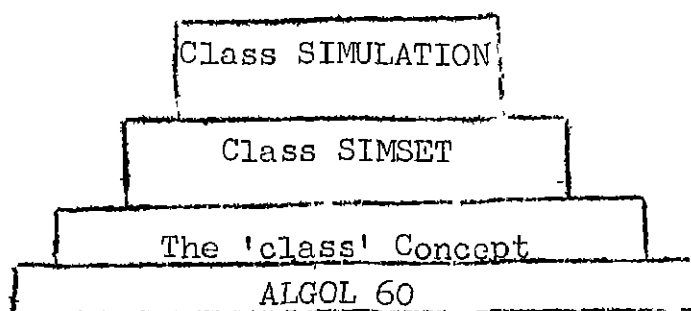
        FIG.2.2 : SIMULA PYRAMID

At the base of the pyramid is the(very slightly modified)

general purpose programming language ALGOL 60. A major addition

to that is notion of 'class', which allows one to define
composite objects containing both data and actions. Two
system defined classes follows. SIMSET and SIMULATION. The
first provides facilities for manipulating linked lists and
and second a clock routine, an event list and parallel processes.
Using classes one can construct complex hierarchial data and
program structures, that is, one can define other classes using
the existing facilities and providing ones of one's own. A
block prefixed by such a class can use both the old and new
facilities.

2.5 COMPARISON OF SIMULATION LANGUAGES

The three popular simulation languages viz., GPSS,
SIMSCRIPT and SIMULA are compared here under the following
broad headings. generality, convenience and efficiency.
Being tied to the concept of block diagrams imposes significant
constraints on the genarality of GPSS. There are, for instance,
certain state-dependent operations that do not lend themselves
readily to description by block diagrams: e.g. multiserver
queues with preemptive priorities or breakdowns, or system
where service rate depends upon number, who are waiting for
service. Such systems are difficult or impossible to simulate
in GPSS. The inability to implement arbitrary numerical
algorithms is also a significant disadvantage. SIMSCRIPT and
SIMULA are completely general both from the simulation and
from the numerical point of view.

On the otherhand, GPSS is the easiest of the three
languages to learn and use. Program written in it tend to be
shorter and easier to debug. The production of reports is
automatic, although inflexible. SIMULA is perhaps more
difficult than SIMSCRIPT to learn, but once learnt it is
easy to use. A point in SIMULA'S favour is that its philosophy
supports and encourages the use of structured programming and
top down design techniques A point in SIMSCRIPT'S favour
is that its statistics collection facilities are more compre-
hensive. SIMSCRIPT is also more widely available than SIMULA
and its compiler is cheaper.

GPSS program tend to be slower than SIMSCRIPT ones,
which, in turn, tend to be slower than SIMULA programs . So
faster, easy to use , language SIMULA, which has scope for
structuring programme is used in present work.

CHAPTER III

MODELLING OF VEHICLE STOPPING AND STARTING FLOW
SEQUENCE IN THE 'ISRTSM' AND ITS APPLICATIONS

3.1 MODEL DEVELOPMENT

Stopping logic modelling consists of representing
deceleration stoppages and acceleration maneuvers when vehicles
encounter signals and similar other spots. The vehicles will
start building up queues in such situations. This aspect of
queuing has been modelled in the queuing sub-model. For
vehicle to become part of such queue it has to be affected by
impediment of halting vehicle. The complete flow logic has
been developed in the microscopic model framework.

3.2 SELECTION OF TRAFFIC MODEL FROM A SET OF MODELS

As presented in review of literature there are several
traffic flow simulation models. Some of them use simple car
following model for the movement of vehicles others take into
consideration stochastic nature of driver decisions in various
maneuvers.

Since stopping of vehicles is necessary at intersections
and such other similar situations along the road, it has been
felt that there is necessity of modelling to represent vehicle
movement in such situations. Since vehicular stoppages are
more prevalent on Indian rural roads than in any western

countries, this modelling needed to be incorporated in such
a traffic flow model which depicts Indian conditions, and
which is highly developed.

One such model which is highly developed and validated
for Indian conditions is 'Indo-Swedish Road Traffic Simulation
Model' (ISRTSM) developed jointly by I.I.T. Kanpur and National
Road and Traffic Research Institute (VTI), Sweden. So the
above model is chosen for incorporation of stopping logic.

3.3 DESCRIPTION OF INDO-SWEDISH ROAD TRAFFIC SIMULATION MODEL

The indo-Swedish road traffic model is a descrete evemt
simulation model which tries to depict the behaviour of a
traffic stream by considering in detail the behaviour of
individual vehicles as they traverse a given section of the
road. The model is stochastic with respect to gap acceptance
under overtaking situations. The position of all the vehicles
on the road is continiously examined on an event basis. An event
can be thought of as each time a decision is required of a
driver.

The model considers four categories of vehicles normally
found on roads. Car group, HMV, two wheelers, Animal driven
vehicles (ADV) have been considered for their behaviour in the
traffic stream. The program system is shown in the Fig. 3.1.
The road description over which traffic flow is to be simulated
is fed into a road making program called 'SIMLU'. This divides
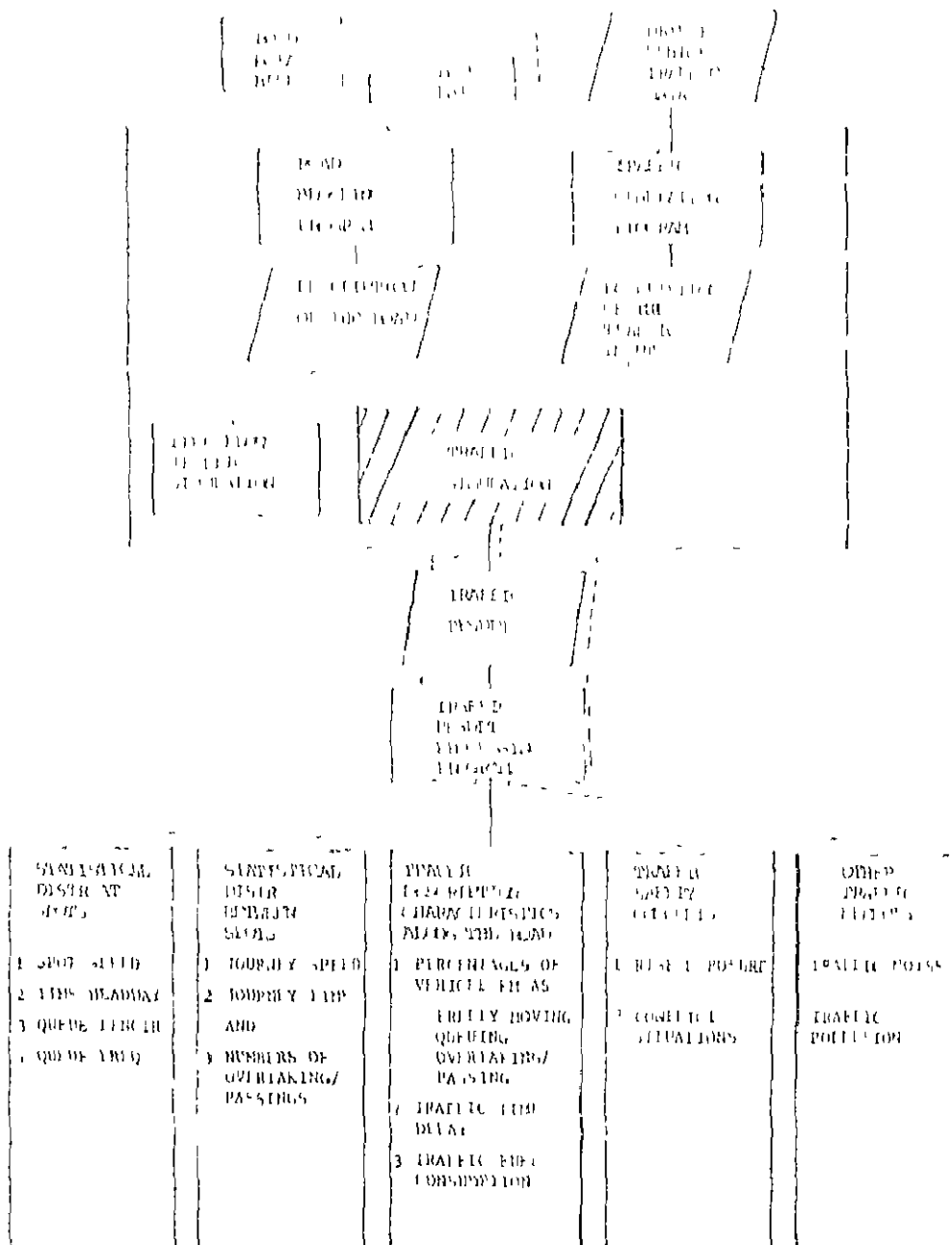
the road into homogeneous block with respect to free block speed, roughness, sight distance etc. The number of blocks is usually 25. It is possible to make more blocks if one desires.

The traffic is generated by both simple and complex traffic generation programs. These programs use the following parameters.

1. Total flow (number of vehicles/hour) .

2. Flow in each direction .

3. Flow changes .

4. Partial flow of heavy vehicles(traffic composition). For the present work vehicles are generated using random traffic generation model proposed by Gillian and Johnson [7]. This program has been written in Fortran and has been used to generate traffic upto 1000 vehicles per hour in increments of 100 vehicles/ hour in each direction.

The Indo Swedish simulation model requires that following traffic characteristics are assigned to each vehicle/driver combination entering the road stretch.

1. Vehicle type .

2. Power/weight ratio .

3. Basic desired speed.

4. Position within the platoon for those vehicles travelling in platoon.

5. Entry speed.

6. Time headway.

3.3.1 Power/Weight Ratios

Each vehicle is defined as belonging to one of the four vehicle types viz. Car, HMV, Two wheeler and Animal drawn vehicle. A seperate marginal distribution of power/ weight ratios was calibrated for each vehicle type . The power of a vehicle/driver combination is the maximum power which the driver is both willing and able to use.

The model used in the simulations to predict the effect of a gradient i on the speed of a vehicle of mass m is

$$m \frac{dv}{dt} = F - F_1 - F_r - mgi$$

where, v = speed of the vehicle at time t

F = Tractive force

F_1 = Air friction force (drag)

F_r = Rolling friction forces

$$m \frac{dv}{dt} = \frac{P}{V} - C_1 AV^2 - C_r m - mgi$$

where, P is the power of the vehicle at time t and C_1, C_r , A - are constants.

or

$$\frac{P}{m} = V \frac{dv}{dt} + \frac{C_1 AV^3}{m} + C_r V + giv.$$

Integration now yields,

$$\frac{P}{m} = \frac{1}{t_1} \int_o^{t_1} P/m \ dt$$

or

$$\frac{P}{m} = \frac{1}{2t_1}(V_1^2 - V_o^2) + 1/t \ (\frac{C_1 A}{m}) \int_{S_o}^{S_1} V^2 ds$$

$$+ \frac{C_r(S_1 - S_o)}{t_1} + \frac{gh}{t_1} \qquad\qquad (3.1)$$

where the left hand side of the equation is the mean power/ weight ratio between S_o and S_1 and t_1 is the time taken between S_o and S_1. These power/weight distributions for all the four types of vehicle have been given in Table 3.1 and plotted in Fig. 3.2, 3.2a, 3.2b.

3.3.2 Basic Desired Speeds:

Five main factors affect the speeds of vehicles on two lane roadways.

1. Driver characteristics.

2. Vehicle characteristics.

3. Load conditions.

4. Traffic regulations.

5. Traffic conditions.

TABLE 3.1:   P-VALUE DISTRIBUTIONS FOR EACH VEHICLE TYPE
             (For Swedish Conditions)

P(W/kg)	Percentage of vehicles accumulated			
	Type 1	Type 2	Type3	Type 4
1	0.	0	0	0
2	0	0	0	0
3	0	0	1.0	3.5
4	0	0.9	6.0	23.0
5	0	3.1	20.4	45.6
6	0.4	12.6	39.5	63.4
7	0.4	24.8	57.2	79.3
8	1.0	39.7	71.4	88.9
9	2.1	48.7	85.7	96.3
10	4.2	64.3	91.6	98.8
11	4.6	78.4	96.7	99.7
12	8.1	85.3	99.5	100.0
13	9.8	93.0	99.8	
14	13.7	97.0	100.0	
15	22.5	98.8		
16	30.2	98.9		
17	40.3	99.0		
18 .	50.2	99.1		
19	60.4	99.4		
20	71.2	99.6		

Table 3.1 contd....

P(W/kg)	Percentage of vehicles accumulated			
	Type 1	Type 2	Type 3	Type 4
21	79.3	99.7		
22	86.4	99.8		
23	89.6	99.9		
24	91.2	100.0		
25	91.6			
26	95.2			
27	96.1			
28	96.1			
29	96.1			
30	97.9			
31	98.2			
32	98.6			
33	98.6			
34	98.6			
35	99.3			
36	99.3			
37	99.3			
38	100.0			

TABLE 3.1(a) : P-DISTRIBUTION FUNCTIONS FOR VARIOUS VEHICLE CLASSES

(For Indian Conditions)

$p\left(\dfrac{w}{kg}\right)$	Cumulative Percentage Frequency		
	Cars	Buses	Trucks
1	1.0	0.0	1.0
2	2.5	2.0	12.5
3	8.5	6.8	40.0
4	17.5	62.5	55.0
5	32.0	86.5	67.5
6	48.0	94.0	79.5
7	66.0	96.5	88.0
8	77.5	98.0	94.0
9	85.0	99.0	98.0
10	90.5	100.0	100.0
11	94.5		
12	97.5		
13	98.5		
14	99.5		
15	100.0		
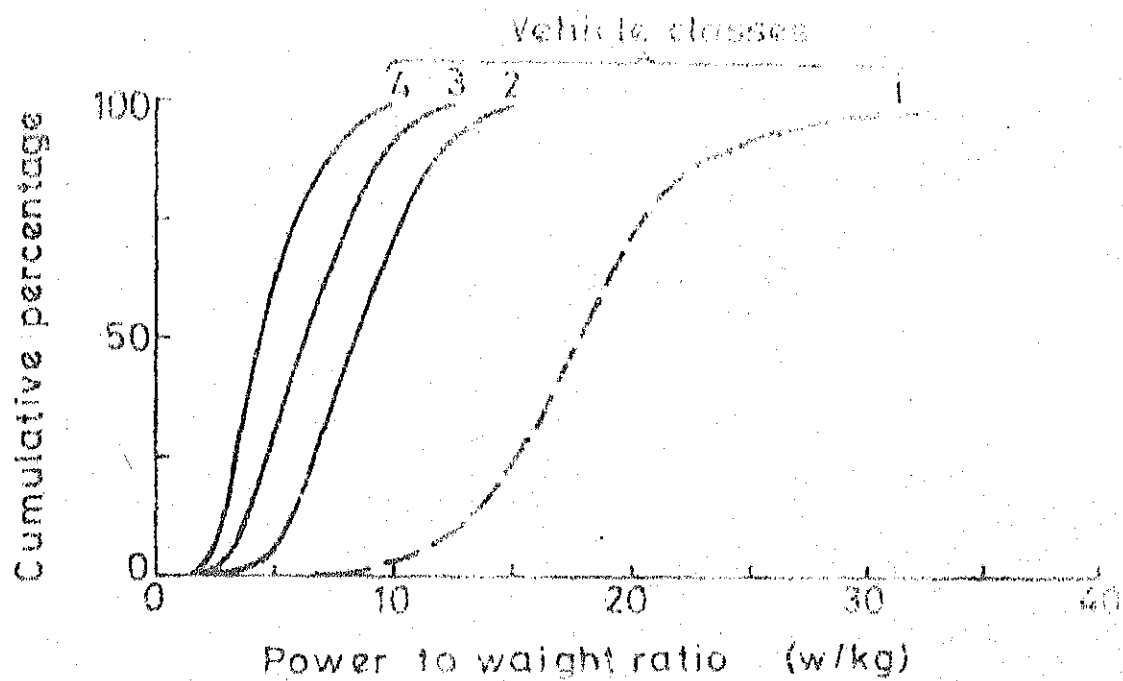
Vehicle classes

FIG. 3.2 p DISTRIBUTIONS FOR EACH VEHICLE
CLASS
(For Swedish Conditions)
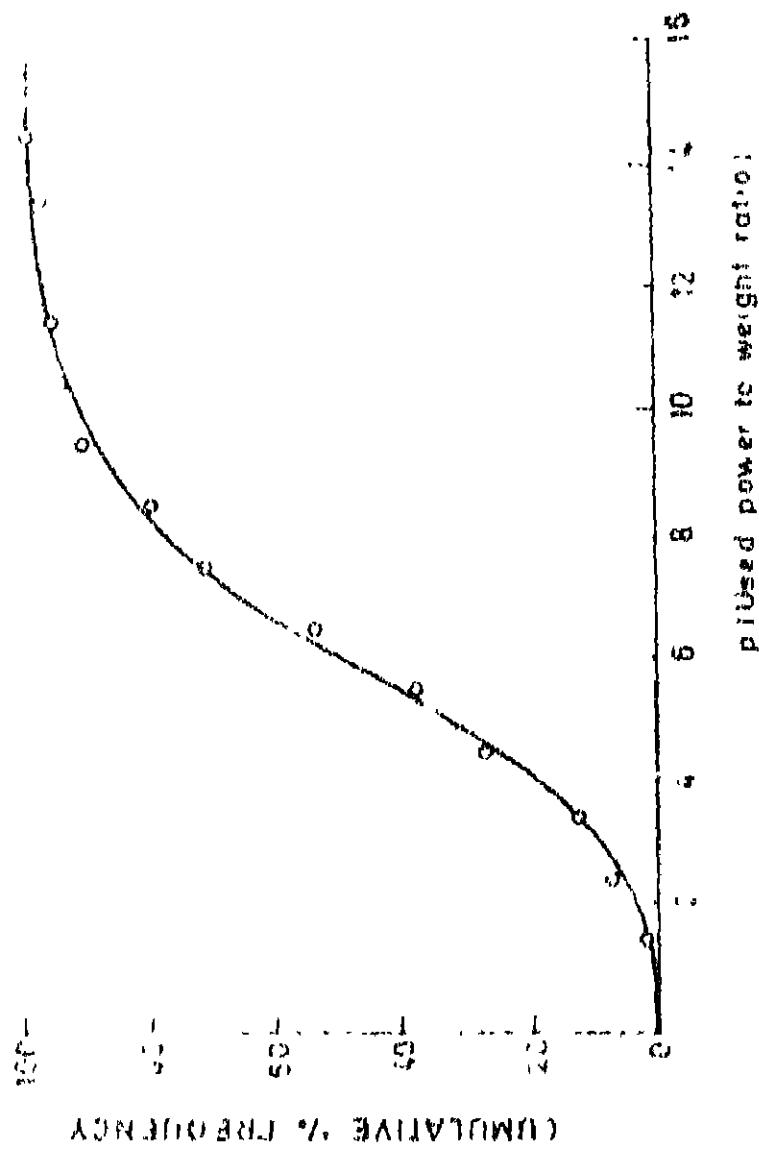
Fig 32ap (USED POWER TO WEIGHT RATIO) DISTRIBUTION FOR CARS

(For Indian Conditions)
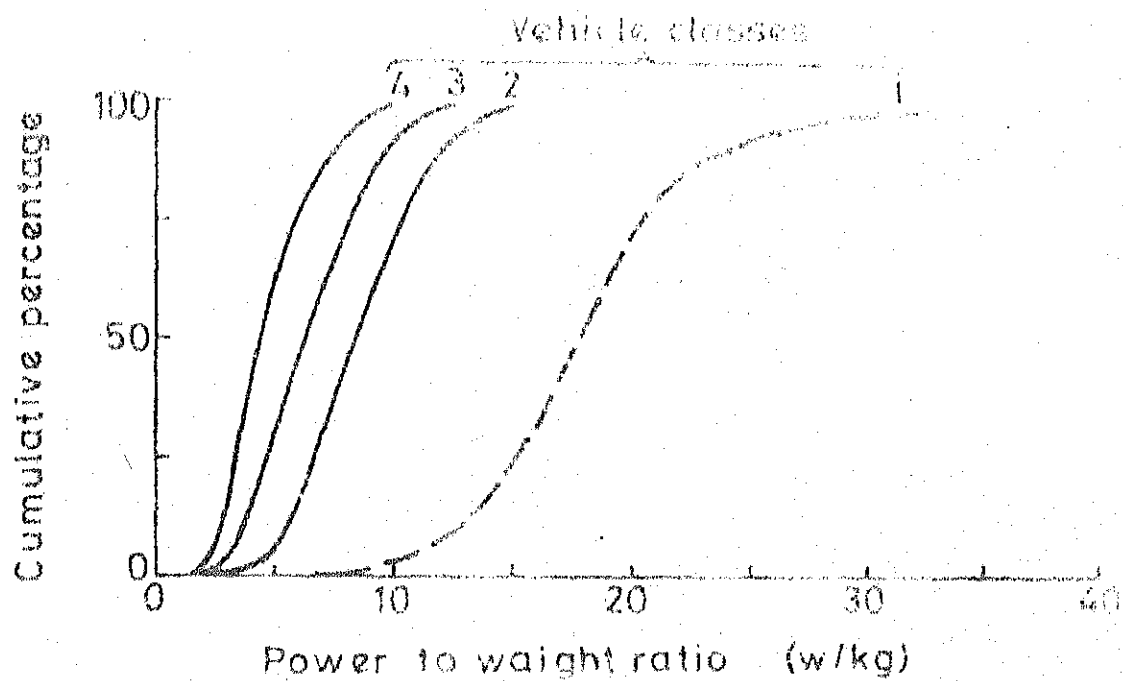
FIG. 3.2 p DISTRIBUTIONS FOR EACH VEHICLE
CLASS
(For Swedish Conditions)
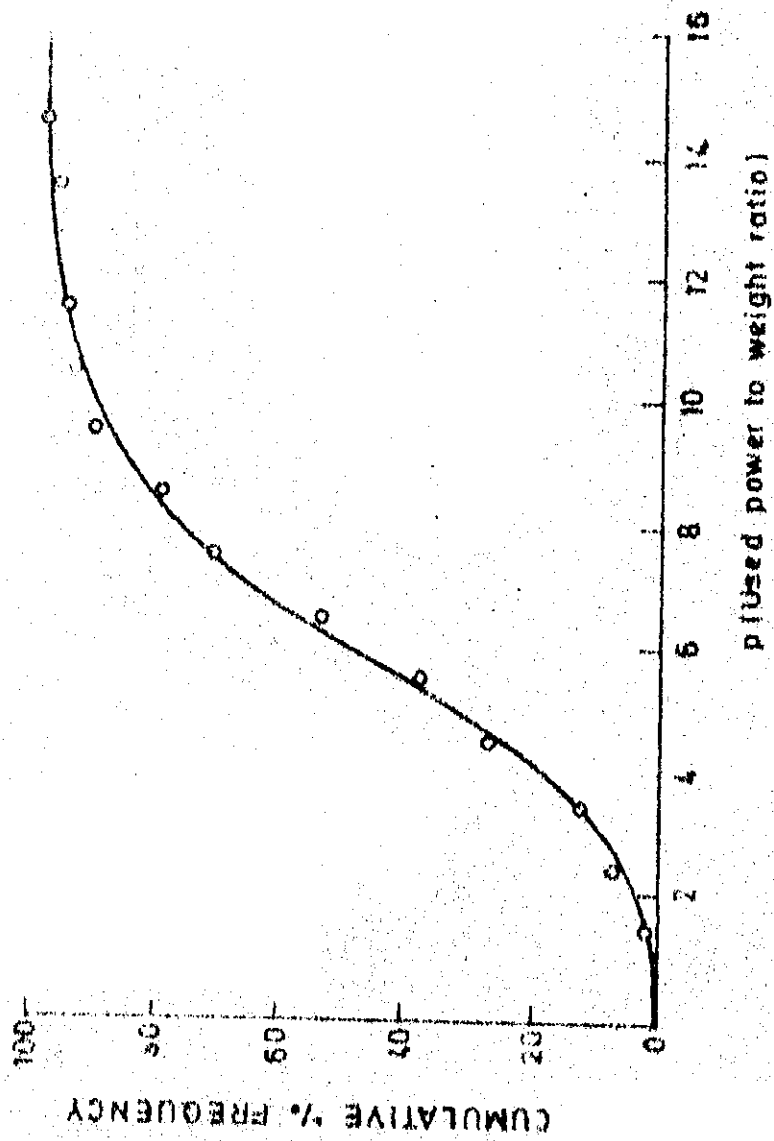
Fig 32 ap (USED POWER TO WEIGHT RATIO) DISTRIBUTION FOR CARS.

(For Indian Conditions)

Basic desired speed is the speed with which the vehicle/ driver combination would maintain, were it not affected by any adverse road and traffic conditions or traffic regulations. Basic desired speeds are ideally measured on straight, wide, flat, two-lane roads under free flow donditions and with no speed limit. The observed distribution was approximated by by normal distribution. The speed classes are given in Table 3.2 and plotted in Fig. 3.3.

3.3.3 Position within Platoon and Time Headways:

The time headway model used is a composite one as used originally by Schuhl [25]. This means that there are two seperate time headway distributions for free moving and constrained vehicles respectively.

The usual form of the composite distribution (probability density function) is

$$f(t) = (1-) g(t) + \cdot h(t) \qquad (3.2)$$

where, $f(t)$ is the probability density function of the composite headway distribution, $g(t)$ is the probability density function of the headway distribution for free moving vehicles, $h(t)$ is the probability density function of headway distribution for constrained vehicles, is the proportion of constrained vehicles.

TABLE 3.2   :   BASIC DESIRED SPEED DISTRIBUTION-FAST MOVING
VEHICLES (FOR INDIAN CONDITIONS)

Speed class in 4 per-centiles	Speed of Cars (Vehicle type 1) m/s	Speed of Bus/Truck (Vehicle Type 2) m/s	Speed of 2 wheelers (Vehicle Type 4) m/s	Speed of All vehi-cles m/s
1	12.50	11.94	9.86	10.14
2	12.64	13.19	10.42	11.11
3	13.33	13.89	10.83	11.81
4	14.02	14.17	11.25	12.36
5	14.58	14.58	11.53	12.78
6	14.86	14.86	11.81	13.33
7	15.42	15.28	11.94	13.60
8	15.97	15.56	12.22	14.03
9	16.25	15.97	12.50	14.31
10	16.67	16.11	12.78	14.58
11	17.08	16.39	13.19	14.86
12	17.36	16.67	13.33	15.28
13	17.64	16.94	13.60	15.56
14	18.05	17.22	13.89	15.97
15	18.33	17.51	14.17	16.11
16	18.61	17.64	14.44	16.53
17	18.89	17.92	14.58	16.94
18	19.44	18.19	14.86	17.36
19	19.72	18.61	15.13	17.64
20	20.00	18.89	15.55	18.19
21	20.69	19.31	15.83	18.75
22	21.25	19.72	16.39	19.17
23	22.36	20.28	16.94	20.00
24	23.47	21.11	18.75	21.11
25	25.50	23.75	22.36	25.00
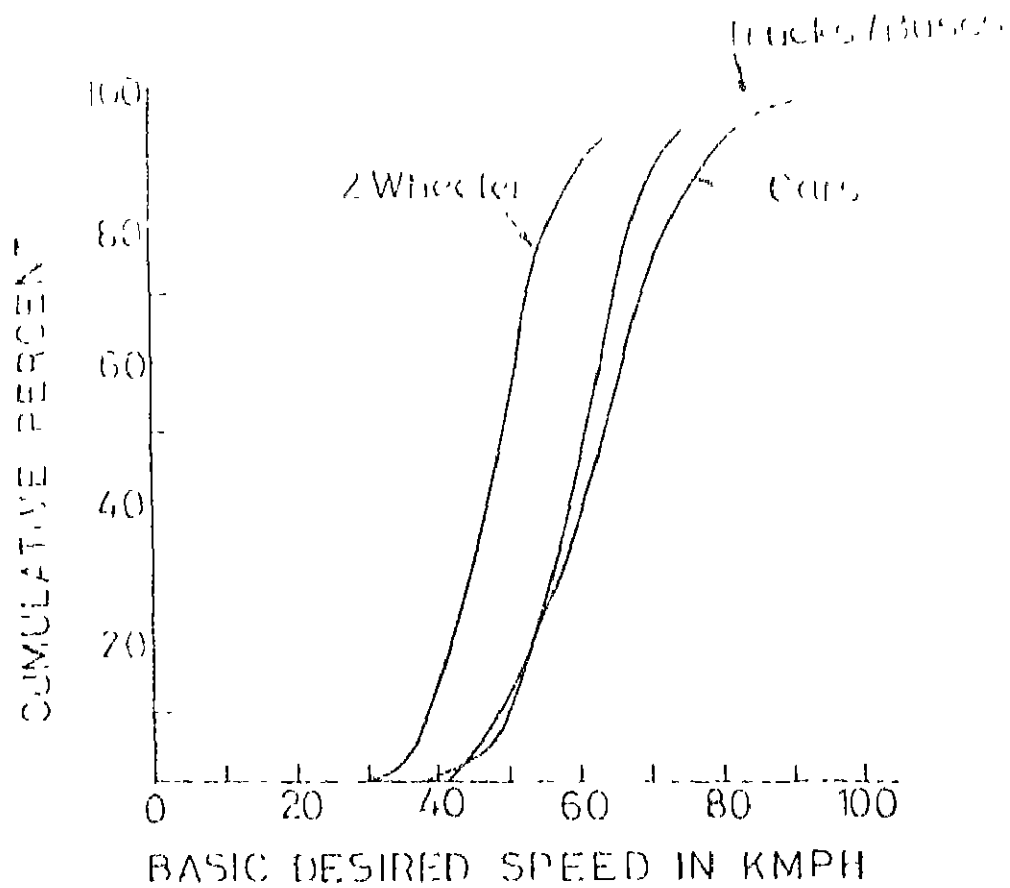
FIG 33 BASIC DESIRED SPEED DISTRIBUTION
(For Indian Conditions)

TABLE 3.2(a): THE V_O DISTRIBUTION FUNCTION

(FOR SWEDISH CONDITIONS)

Speed class	$V_O(n)$ (m/sec)	Speed class n	$V_O(n)$ (m/sec)
1	18.20	14	27.30
2	20.35	15	27.75
3	21.47	16	28.20
4	22.32	17	28.68
5	23.04	18	29.19
6	23.64	19	29.74
7	24.16	20	30.34
8	24.64	21	31.00
9	25.11	22	31.72
10	25.56	23	32.66
11	26.00	24	34.29
12	26.43	25	37.50
13	26.86		
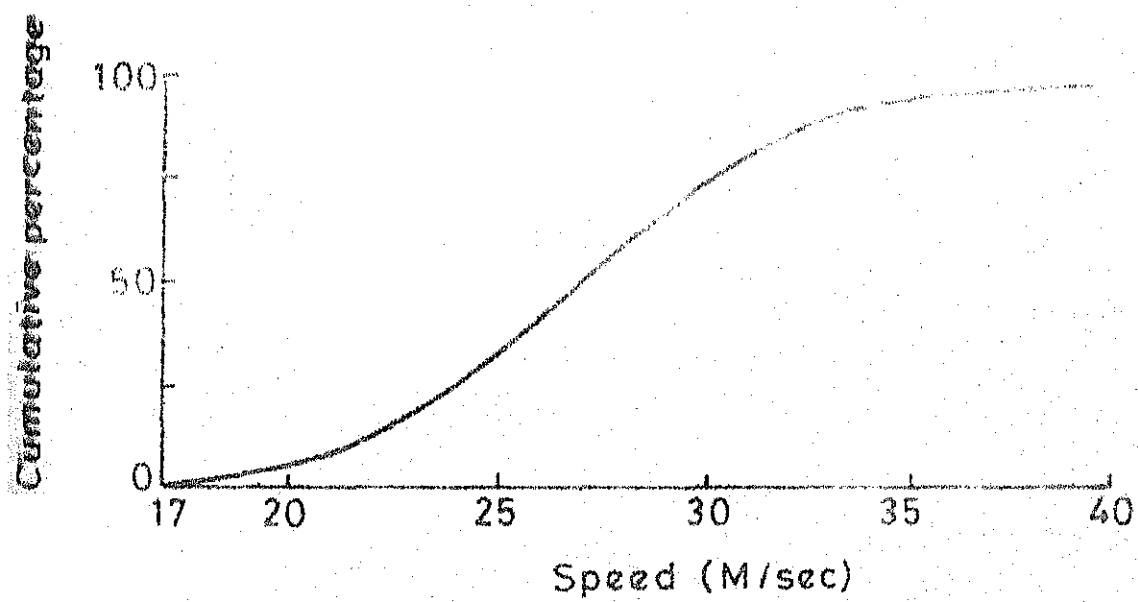
FIG. 3.3a V_0 - DISTRIBUTION
(For Swedish conditions)

The log normal and exponential distributions have been used to represent the time headway distributions of constrained and free-moving vehicles, respectively.

3.3.4 Time Headway Distribution for Constrained Vehicles (Log-normal):

Branston [2] has analysed constrained time headways on two way roads in Indiana, U.S.A. He found that a log normal distribution fitted the data with mean of 2 seconds and a standard deviation of logarithms of constrained headways σ_c of 0.45.

3.3.5 Time Headway Distribution for Free Moving Vehicles (Exponential):

This distribution is completely determined by mean μ_f. Now the total headway for a platoon length η is the sum of one headway for a free moving vehicle and $(\eta-1)$ mean headways for constrained vehicles. Hence, taking expected values,

$$\frac{\mu}{q} = u_f + (u-1)\,\mu_c \qquad (3.3)$$

where,   q   is the following traffic flow

        μ is the mean platoon size

        μ_c is the mean headway for constrained vehicles.

3.3.6 Platoon Size Distribution:

Estimating the parameters m and S is equivalent to estimating the mean platoon size, u , and the expected proportion of platoon size 1, δ. This is because

$$\mu = \frac{(m+S+1)}{m} \tag{3.4}$$

and

$$\delta = \frac{(m+1)}{(m+s+2)} \tag{3.5}$$

and this pair of equations can be solved for m and s. Miller [14] has shown emphrically that

$$\frac{1}{\mu} < \delta < \exp\left(-\frac{(u-1)}{\mu}\right) \tag{3.6}$$

and from their data it seems reasonable to approximate δ by the estimate

$$\delta = \frac{1}{2}\left(1/\mu + \exp\left(-\frac{(\mu-1)}{\mu}\right)\right) \tag{3.7}$$

Further more Miller [14] found that

$$u = 0.58 + 1.58Z \tag{3.8}$$

where, $Z = \dfrac{0.1\,q}{\lambda(1-qu_c)}$

where, λ is the overtaking rate for constrained vehicles.

The problem of estimating μ is therefore reduce to that of estimating for a given road and traffic flow. Miller[14]

has used data collected on a single straight two lane road in Sweden to produce the estimate.

$$\lambda = 2750 \; Q^{0.62} \qquad\qquad (3.10)$$

where, Q is the oncoming traffic flow.

The observed following traffic flow, q and observed proportion, θ of the time headways less than 4.8 seconds were used to estimate u for each data set as follows.

P_γ (Head ≤ 4.8) = P_γ (constrained vehicle)

x P_γ (constrained headway ≤ 4.8)

+ P_γ (free moving vehicle) x P_γ(free moving

headway ≤ 4.8) $\qquad\qquad (3.11)$

$$\theta = (1 - \frac{1}{\mu}) \; P_\gamma \; (L(\mu_o{}^\sigma) \leq 4.8) + (1/\mu)$$

x $(P_\gamma(E(\mu_f) \leq 4.8)$

Finally

$$\theta = (1 - \frac{1}{\mu}) \; x \; 0.96 + \frac{1}{\mu} \; (1-\exp(\frac{-4.8}{\mu/q-(\mu-1)2.4}))$$

$$(3.12)$$

Given θ and q this equation may be solved for μ (for each data set' and hence λ may be estimated (for each data set), by substituting μ into equations (3.1).

3.3.7 <u>Probabilities of Gap Acceptance</u>:

The probability of accepting a gap of given length in order to overtake is required by the model in each of 32 different overtaking situations viz.,

Overtaking maneuvers   -   (1)   Flying

                                 (2)   Accelerative

Limitation   -   (1)   On coming car

                                 (2)   Sight distance

Vehicle overtaken   (1)   Vehicle class 1, travelling
                                       at a speed < 72 km/hr.

                                 (2)   Vehicle class 1, travelling
                                       at a speed $\geq$ 72 km/hr

                                 (3)   Vehicle class 2

                                 (4)   Vehicle class 3 or 4

 Road width   -   (1)   There exists a hard shoulder
                                       2m or a climbing lane

                                 (2)   Neither of this exists.

The following is the relationship for probability of gap

acceptance.

$$P(X) = \begin{cases} 0 & \text{if } X \leq S_1 \text{ m} \\ a^{(X-S_1)/(S_2-S_1)} & \text{if } S_1 < X < S_2 \text{ m} \\ a & \text{if } S_2 \leq X \quad \text{m}^2 \end{cases}$$

where   X is the gap distances and a, S_1, S_2 are callibration

constents.

3.4 DEVELOPMENT OF STOPPING ALGORITHM AND QUEUE SUBMODEL:

When it is decided to introduce stoppages in the
traffic flow model, it is necessary to consider the situations
where vehicles usually stop on roads. They stop usually
near bridges, signals etc. Modelling of stopping near signals
are more complex than modelling stoppages near narrow bridges,
in the sense vehicles will stop near signals only when signal
is red, where as in case of narrow bridges vehicles always
stop .

In this study, stopping near signals have been modelled.
For this simulation of signals were also incorporated in the
original traffic model. The yellow period between red and
green and green and red were merged to red and green respecti-
vely. The model has been structured so that it is capable
of representing vehicles moving in yellow periods also.

Incorporation of signal simulation in the model
included, introducing red to green or viceversa signal changes
as the events in addition to the events already present in
the model.

The simple logic followed for the above purpose is as
given below.

If vehicle has stopped then:

Next event time is equal to, time when signal
becomes gree plus, vehicle position in the signal queue times
reaction time of the driver.

Otherwise:

Next event time is lesser of the predict next event time(as in the original model) and time when signal changes next plus vehicle position in signal queue times reaction time of the driver.

It is assumed that vehicles will decelerate from such a point, from where it can come to halt with maximum deceleration equal to $2m/sec^2$ either on the stopline if it is first in the queue or behind another vehicle with sufficient gap between them if the vehicle is not first in signal queue.

Since the vehicles and driver unit in ISRTSM model, are considered as point object, to know how much should be spacing between vehicles when they have stopped, the dimension of different vehicles were essential. The assumed dimensions of different vehicles are given in the Table 3.3.

TABLE 3.3 : DIMENSIONS OF THE VEHICLES

Types of vehicles	Length (in mts)
1 Passenger car	4.60
2 Bus/Truck	9.35
3 Autorikshaw	2.75
4 Scooter and Motorcycles	1.90
5 Bycycles	1.90

In the representative road the signals are installed at places as shown below in Fig. 3.4.

For starting the vehicles from stoppage an initial velocity of 1.0 m/sec was assumed and the initial acceleration assumed was 1.00 m/sec^2 for faster vehicles and 0.75m/sec^2 for slow moving vehicles. A vehicle will become member of signal queue if and only if it is affected by the signal, thus causing some delay when compared to its free flow conditions. A vehicle can be in signal queue both during red and green phases of the signal. This aspect is modelled as signal queue submodel.

The vehicles are discharged from the head of the queue and for this movement one should determine the position of the vehicle in signal queue. To do this a logic was developed which is as follows.

Let Vb be any vehicle

STEP1: If signal queue is empty position of Vb in queue =0. Go to step 12

STEP2: If Vb is first in signal queue position of Vb in queue = 1. Go to step 12

STEP3: If there is no vehicle behind first vehicle of the queue then position of Vb in signal queue=0. Go to step 12

STEP4: Let Vf2 refer to vehicle present behind first vehicle of the queue

STEP5: If Vb = Vf2, go to step 8 otherwide go to step 6

STEP6: If Vf2 is last in queue, position of Vb in queue =0. Go to step 12.

STEP7: Let Vf2 refer to vehicle present behind previous Vf2. Go to step 5.

STEP8: Position of Vb in queue = 2. Go to step 9

STEP9: Let Vf refer to vehicle infront of Vf2. Go to step 10

STEP10: If vehicle Vf is queue first then go to step 11

STEP11: Let Vf refer to vehicle present ahead of previous Vf

STEP12: Exact position of Vb in queue = position of Vb in queue.

The reaction time of drivers are assumed to be 2.5 secs. The other assumption in the model is that, signal is situated only on the block border of homogeneous road block. The complete sequence of flow of vehicles obeying signal is programmed according to the following logic.

STEP1: Check whether the vehicle has crossed signal post. If it has ; crossed go to step 3; else go to step 2.

STEP2: Check the status of the signal. If the signal is red for the direction of travel, go to step 3, if green to to step 18.

STEP3: Check whether there is a vehicle infront of the present vehicle. If there is a vehicle go to step 4 else go to step 5.

STEP4: Check the position of front vehicle. If it has not crossed the signal post and is at such a position, it can come to halt with permissible deceleration then go to step 6 else go to step5.

STEP 5 If the present vehicle is the nearest one to signal post when signal turns green from red. Then go to step 6 else go to step 33.

STEP6: Check whether the vehicle can stop with permissible deceleration value thus responding the red signal for the direction of travel. If it can stop go to step 7 else goto step 15.

STEP7: Find out whether signal becomes green for the direction of travel before or by the time vehicle reaches such a point it starts decelerating to stop. If so goto step 18 else goto step 8.

STEP8: Move the vehicle upto a point from where it starts decelerating (stopping sight distance) and check whether by the time vehicle comes to half with reduced signal becomes green. If so go to step 17 else go to step 9.

STEP9: Make the vehicle to halt near the signal line. Enter this vehicle into signal queue of the direction and goto step 33.

STEP10: If the front vehicle has stopped goto step 12 else if it has not stopped but is in moving condition goto step 11.

STEP11: Find whether the front vehicle is the last vehicle in the signal queue for the direction. If it is the last one goto step 12 else goto step 33.

STEP12: If the vehicle is in overesttriction zone of the signal environment goto step 14 else go to step 13.

STEP13: Find out distance between the present vehicle and the one in front of it. If they are very close goto step 14 else goto step 33.

STEP14: Enter the vehicle into signal queue of the direction and goto step 33.

STEP15: Increase the counter keeping count of number of vehicles moving in yellow period between red to green changes. Goto step 33.

STEP16: Wait till signal becomes green and goto step 18.

STEP17: Increase the counter keeping count of vehicles partially delayed by signals by one and goto step 33.

STEP18: Find out whether there is queue built due to signal. If there is queue goto step 19 else goto step 22.

STEP19: Increase the counter keeping account of number of signal cycles fully made use by vehicles by one and goto step 20.

STEP20: Check whether front vehicle has stopped. If stopped goto step 17 else goto step 21.

STEP21: Check whether the front vehicle is in such a position that it can come to halt with permissible deceleration. If it can stop goto step 26 else goto step 22.

STEP22: Check whether the present vehicle is nearest vehicle to signal post when signal turns red next. If so goto step 12 else go to step 33.

STEP23: Find out the position of the vehicle when signal turns red.

(i) If the vehicle will be past the signal post by the time signal becomes red goto step 24.

(ii) If the vehicle will be in such a position that it is the nearest one to signal post but can not stop with permissible deceleration then goto step 25.

(iii) If the vehicle will be in such a position that it is the nearest one to signal post and can stop with permissible deceleration then wait until signal becomes red and goto step 3.

STEP24: Increase the counter keeping account of vehicle un-affected by signal and goto step 33.

STEP25: Increase the counter keeping account of vehicles moved in yellow period between green to red change and goto step 33.

STEP26: If the front vehicle is last in the signal queue of of the direction then go to step 27 else goto step 33.

STEP27: If the vehicle is in over restriction area of the signal environment then goto step 29 else goto step 28.

STEP28: Find out the distance between the current vehicle and the one in front of it. If they are very closely spaced then goto step 29 else goto step 33.

STEP29: Enter the vehicle in the signal queue of the
direction and goto step 30.

STEP30: If the current vehicle halted then goto step 32
else goto step 31.

STEP31: Increase the counter keeping account of vehicle discharged
from signal queue in green period and goto step 33.

STEP32: Wait till the current vehicle becomes the first
vehicle of the signal queue and start the vehicle
by giving it an initial velocity of 1.0 m/sec
and goto step 33.

STEP33: Move the vehicle as in the original Indo-Sweedish traffic
model. Goto step 34.

STEP34: Check whether vehicle has reached it's destination.
If it has not reached then goto step 1 else goto
step 35.

STEP35: Check whether maximum vehicle generation time or
simulation cut-off time has reached. If it has
reached then goto step 36 els. goto step 37.

STEP36: Generate another vehicle and move the vehicle using
the logic of step 1 to step 36.

STEP37: Print the results and stop.

3.5 APPLICATION OF THE MODEL

3.5.1 Simulation of Signalized Intersections

Present model can be directly used to simulate signa-
lized intersections. Such simulation will help engineers to

know whether the already fixed time of signals are performing at a desired level or there is need to change the timings. This can be determined by identifying measures of effectiveness. Some of the measures of effectiveness usually considered are (i) Proportion of delayed vehicles and delay times of different catagories of vehicles (ii) Load factor or degree of utilization of the signal and (iii) Queue length of different catagories of vehicles of various approaches. Also we can optimize signal timings.

We can also establish the effect of variation of signal timings and overtaking restriction zone lengths(usually dividers) on the queue lengths and utilization and delays for vehicles. We can also estimate increased fuel consumption due to effect of signals on the vehicles. Also we can determine the effect of increasing or decreasing overtaking resfriction zone near intersection on fuel consumption, as fully validated fuel consumption model in ISRTSM is reported.

3.5.2 Establishing Volume Warrants:

Volume warrants are nothing but an index which indicate when to go for signalization of intersections. The present model can be used to simulate both unsignalized and signalized intersections with a bit of modifications.

We can establish volume warrants by simulating the same intersection with and without signals. The difference between the measure of effectiveness of two such experiments help in establishing volume warrants.

3.5.3 Simulation of Density Scanners:

Density scanners are one of the types of traffic controlling devices. These are traffic actuated unlike pre timed signals, here timing of red and green period gets adjusted proportional to the volume of traffic present on the approaches of intersections.

Usually for each vehicle entering the signal queue the green period increases. The entry of vehicles are scanned by electronic scanners. There will be fixed maximum green period beyond which the signal turns red for the approach. These types of signals are defnitely better than preactuated signals, if one ignores the cost.

Scuh scanners can be easily s_mulated in the present model. With slight modification in the 'Procedure system signal' of the present model. At present green timing and red timings are fixed but this can be replaced by length of the signalqueue times fixed increment of time in green period per vehicle. Signal queue length at any time can be refered
by simula's built in attribute of doubly/ linked list called 'cardinal'.

3.5.4 <u>Simulation of System of Signalised Intersection and</u>
      <u>Unsignalised Intersections</u>

The present model can be modified to simulate system
of signalised and unsignalised intersections. The result
of such simulation will be useful in fixing timings of
signals of various intersection on   entire network
minimising the total delay of travel time.

The needed modifications in the present model are,
the'procedure action signal' should be converted to a class.
The class will have the attributes,signal timings ie both red
and green period and location of signal post, coordinates of
overrestriction zone begining. The class can be called when-
ever signalised intersection is encountered in the movement
of vehicle while it will follow usual logic of ISRTSM on
other times.

3.5.5 <u>Accident Model and Accident Analysis</u>

The present model can be used to create accident of
vehicles. Such modelling will help in accident analysis
which in turn is essential for loss prevention of life.

Accident is said to occur in the model,if different
vehicles occupy same coordinate at same time having same
predecessor and successors.

In the original ISRTSM model at no time head and
tail of vehicles are allowed to overlap. In the present model

with certain probability tail and head of vehicles can be allowed
to overlap thus causing accidents.

The probability can be ascertained from field study
and this can be allowed to occur at such places where casuality
taking place regularly.

CHAPTER   IV

INPUT AND OUTPUT OF THE MODEL

4.1   INPUT OF THE MODEL:

Input to the model consists of a road file, traffic
file and model data. Road file is nothing but description
of the road on which vehicle is to be moved. This is created
by another program to which following field data are fed.

For each block in each direction

1.   A coordinate for the begining of each block in mts

2.   Carriage width maximum 7m

3.   Hard shoulder width in dm

4.   Speed limit in km/h

5.   Gradient in percentage

6.   Curvature 10^4 m^{-1} (The curvature is the inverted value
       of the horizontal radius) following data describing sight

7.   A coordinate for the begining of each sight section
       in meters

8.   Sight distance at this coordinate
       and the following data about overtaking restriction and
       hard shoulder

9.   A code for over restriction

10.   A code indicating hard shoulder/climbing lane presence.

Traffic file having following vehicle data:

1. Identify number

2. Vehicle type

3. Basic desired speed in m/s

4. P-value(Power/weight ratio) in w/kg

5. Direction

6. Coordinates for entry to and exit from the section in meters

7. Time and speed at entry to the section

and the Model data mentioned below

(1) Probabilities of overtaking at different coordinates

(2) Time headways for different types of vehicles

(3) Deceleration value

(4) Rolling resistance

(5) Air resistance coefficient

(6) Probability of vehicle going to lane 3.

(7) Extra speed in track 1 etc.

and following general data

(1) Maximum vehicle generation time

(2) Data collection points

(3) Random number speed

(4) Simulation cutoff time.

huge

Table 4.1 contd....

Information type	Occasion	Short description of result	
12	opportunity for accelerated over-taking not accepted	as for type 4	O
13	block border passage	equipage status, basic de-sired speed, equipage type and power/weight coeffi-cient, energy consumption	B
14	every change	equipage status, predicted times and speeds, etc.	C
15	overtaking is interrupted be-fore level point	equipage status	U
16	overtaking is finished after levelpoint	equipage status	U
17	following ter-minated	equipage status	U
18	overtaking level-point	equipage status, identity, coordinate, speed and type of 1) the overtaken and 2) the oncoming vehicle	L

+) equipage status refers to identify, road and time coordinates, speed and track

U = unconditional result
B = conditional result
O = conditional result
L = conditional result
C = conditional result after time specified.

CHAPTER V

RESULTS DESCRIPTION AND CONCLUSIONS

5.1 RESULTS DESCRIPTION:

In the present traffic model vehicles are moved
depending on vehicular interactions, the quality of road on
which vehicle is moving and the stochastic behaviour of
drivers. The scanning or shifting of time takes place event
wise.

Results are printed in event file, in detail giving
account of every individual vehicular movement as and when
an event occurs. The first few rows of the output contains
the details of the input fed for simulation such as maximum
vehicle generation time, name of the road file, coordinates
of the data points at which data are collected for validation
purpose, rolling resistance for different types of vehicle,
deceleration value, air resistance, time headways for categories
of vehicles etc. These are denoted by event number '0' at the
start of a row.

First column of the event file denotes the event
number on which   account the status of the vehicle being
output.   The various events in the model are,

    1)   Entry of vehicle on a section of road.

    2)   passing block limits.

In the model, the road on which vehicles are moved
are divided into specified number of homogeneous road blocks.
Vehicles are moved from block to block in the absence of
any other intermediatary events.

3) Catching a preceding equipage.

4) Tailing begins.

If the fast moving vehicle meets the slow moving
vehicle on the same track, there exists two alternative
either to overtake or to adopt speed to tail the equipage.
Taillength of the vehicles are given in seconds for different
categories of vehicles.

5) Passing a maximum sight point

The sight distance along the road is approximated
with a sectionally linear function. The point where this
sight distance function has maximum is called maximum sight
point. For accelerated overtaking, vehicle has to wait till
they reach these points.

6) The equipage meets another equipage in on coming lane.

7) Overtaking begins.

8) Equipages level during overtakings.

9) Conclusion of overtaking when the overtaken.
equipage is not tailing .

10) Exit to hard shoulder/climbing lane .

11) Return from hard shoulder/climbing lane to normal lane.

12) An equipage is caught up.

In addition to their original events, the below.
events are introduced in the present work.

13) Signal becoming red .

14) Signal becoming green .

15) The point when vehicle starts decelerating due
to the effect of signal.

16) The vehicle coming to stop .

17) The vehicle starting from stoppage.

The event file gives every detail of vehicle movement. For
accomplishment of specific needs, the event file are further
processed through specific post processing programme.

5.2 CONCLUSIONS AND SCOPE FOR FUTURE WORK:

In the present thesis the vehicular stoppage on roads
and their starting has been modelled. The effect of such
stoppage is queue formation and delay to vehicles. The
queue formation has also been modelled.

The present thesis shows the need for stopping logic
in the traffic model by exploring the possible benefits by
indicating the applications of the logic. The model at present
state has only shown the way the stoppage can be modelled.
The stopping spot reconsidered in modelling is traffic signals.
It is assumed vehicles stop with permissible deceleration,
and certain fixed acceleration values are assumed at the start
of vehicles. The road files used and signal timings assumed

and traffic files are fictitious.

Before model is fully put to its potential use the following works to be carried out.

(1)   For any simulation model to be used, it is to be validated. Since almost whole 'ISRTSM' model stands validated, the present sub-model needs validation.

(2)   In calculating stopping distance of the vehicles only deceleration acceptable was taken as criteria. However, stopping distance depends upon drivers behaviour (PIEV concept) . Efficiency of brakes, Frictional resistance between the road and the tyres and slope of road surface if any. A detail study should go on to define stopping distances of vehicles, taking all the above factors into considerations.

(3)   The composition of traffic and geometrics of the highway may be varied along with the period of signal and the effect of these factors on the figure of merits can be studied. In this model straight road way with ideal geometric features are assumed.

(4)   In the model vehicles have been assigned some predetermined fixed headways without taking the changes of headways during the interaction of vehicles at different speeds and the intensity of interaction (depending number of vehicle) into account.

(5)   Random nature of queue formation and queue dispersion near signals prevelent in Indian conditions should also be thought off and should be incorporated in the model.

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APPENDIX - A

DESCRIPTION OF IMPORTANT PROCEDURES

AND VARIABLES IN ISRTSM

THE ROAD

In the program the stretch of road considered consists of a sequence of consecutive road block objects and a sight distance function in each direction of travel. Each road block object is homogeneous with regard to the following road geometry and traffic regulation parameters:

1. Road width and road surface type
2. Auxiliary lane/lateral space (i.e. wide shoulder)
3. Slope
4. Horizontal curvature
5. Speed limit
6. Overtaking restriction

The road block is represented in the program as an object from the class ROADBLOCK. This object has the following attributes:

I Location and length

   RC0   coordinate of road block beginning
   RBLENGTH   road block length

II Road geometry and Traffic regulation attributes

   ROADWIDTH   road width class
   LANE   occurrence of auxiliary lane/lateral space
   RI   slope
   RQ   Q value
   DVQ   block speed for median equipage ** RQ - basic
                  desired speed for median equipage ** RQ
   RNOMOVERI   code relating to overtaking restriction

III References

   PSIGHTMAX   occurrence and coordinates of sight
                  distance maximum
   PSIGHTREF   reference to distance length function

The road block object is linked in each direction in a SIMSET list with the headings DIRECTION1 and DIRECTION2 respectively.

The sight distance at different points along the road is approximated with a linear function of the road coordinate. One function is required for each direction of travel.

The sight distance function is represented for direction 1 in the program by coordinate pair (BREAKPCOORD1), SIGHTDIST1) and in a corresponding way for direction 2.

To facilitate determination of the sight distance at an arbitrary point along the road, the road block has here, as mentioned above, been given a reference to the sight distance function in the same direction.

PSIGHTREF=n if $S_n \leq RCO < S_n + 1$ where S_n and $S_n + 1$ are road coordinates for two consecutive breakpoints and WK is the road coordinate of the road block beginning.

EQUIPAGE

Equipage attributes and global behaviour

In the program the equipage is represented as an object of the class VEH. The object has the following properties. (I/O) or synonymous (I/O) attributes:

I   Administrative attributes

IDNU	I/O	identity number
DIRNU	I/O	direction number
ORIGIN	I/O	coordinate of the road for start of equipage
OWNTRACK	I/O	track number
DEST	I/O	coordinate of the road for termination of equipage
HIGHW	I/O	destination reached

II   Driver-vehicle attributes

VON	I/O	basic desired speed
TIMEHEADWAY	I/O	time heads v
MINTIME	I/O	shortest stay in auxiliary lane/lateral space after passing
PNORMAL	I/O	power/weight coefficient allotted
P	I/O	Calculates the p-value for the vehicle. If the vehtype is 1 (private car) and in track 1 then the vehicle receives a stronger p value. In this case

$$P = \begin{cases} 40 \text{ if PNORMAL} \ge 32.5 \\ \text{PNORMAL} + 7.5 \text{ if PNORMAL} < 32.5 \end{cases}$$

otherwise

P = Pnormal

| VEHTYPE | I/O | vehicle type |

c 2	LX	air resistance coefficient
c 1	LX	rolling resistance coefficient
W	EN	accumulated energy consumption

III   Traffic attributes of the equipage

FOLLOWING	FN	equipage is following
BEHCATCHUP	EN	equipage is caught up
LOCALCOORD	FN	road coordinate at preceding event
LOCALTIME	EN	time of preceding event
LOCALSP	EN	speed at preceding event
AVERSP	FN	speed from preceding event to next event
PREDICT-NEXTEVTIME	LN	predicted time of next event
PREDBI-BORDERTIME	LN	predicted time of passage of next road block border
PREDICTBI BORDERSP	LN	predicted speed at passage of next road block border
FREEBLSP	EN	free block speed

IV   References

| BLOCK | EN | reference to actual road block |

The events are assumed to occur momentarily at calculated times. At each event the model data is updated and a particular event generated from among the possible consecutive event types. A note of the predicted event is inserted chronologically and logically in a list (SQS) and the events are then executed in this order.

The ordinary cycle for an arbitrary equipage is:

1.   Predict the time of the next event - PREDICTNEXTEVTIME
2.   Await the predicted time -- HOLD -
3.   Move the equipage in time and space - DRIVE -

During phase 1 of the cycle PREDPROB... a... aval, PREDHEADWAY, AVERSP and PREDICTEDAVERSP are... delivery in procedure TIMEFIX. During phase 2 of the cycle the procedure PHI updates the attributes LOCALHAC, LOCALCOUNT, ... P, AVERSP PREDHEADWAY and PREDICTEDAVERSP

During phase 3 of the cycle it may happen that when a preceding interacts with the current equipage with the result that the predicted time of the next event for this equipage is short incorrect since it will occur earlier. Its ordinary cycle is consequently not required and the current equipage considers that a "surprise" has occurred, through the SURPRISE procedure. A previously... a next ordinary event on the equipage is then made.

Each equipage has been allocated a "head" and a "tail". The equipages constantly attempt to drive so that their heads do not overlap their tails. The lengths of the heads and tails are defined as:

$$\text{head length} = \frac{(\text{AVforw}-\text{AVERSP})^2}{2 \cdot \text{DACC}} \quad \text{if AVforw} < \text{AVERSP}$$

$$0 \quad \text{otherwise}$$

$$\text{tail length} = \text{TIMEHEADWAY} \cdot \text{AVERSP}$$

where AVforw is AVERSP for a preceding equipage. Head length therefore indicates the distance required to slow down with given retardation DACC to the speed of the preceding vehicle. The tail length is chosen so that equipages in a queue are separated by given time intervals.

An important aspect of the program is that a road is divided into a number of lanes, where each equipage in each lane behaves in a defined manner.

Direction of traffic: Direction of traffic:

a) ▸right-hand traffic   a) ◂ right-hand traffic

b) ◂ left-hand traffic   b) ▸ left-hand traffic

An equipage can use three of the four lanes. Lane 2 is the ordinary lane in the direction of travel and lane 3 is a wide shoulder or auxiliary lane. In lane 1 priority is given to traffic in the opposing direction.

An equipage remains in its lane until it decides to change lanes. The reason for this decision may be in order to overtake, i.e. move out into lane 1 or alternatively move onto lane 3 to allow a catching-up faster equipage to pass.

Short description of equipage procedures

To acquaint the equipage as to which of the many complicated situations is in force, a number of procedures and variables are provided.

These situations are listed and described below. A brief description of the predicting routines i.e. the procedures which, among other things, calculate the time to a given next event, is also provided. The latter procedures are similar in that they all give a time to the next block border if this event type occurs before the given event.

Variables controlling behaviour

Basic routines

PREDICTCOORD   calculates the road coordinate for current equipage at the particular time (i.e at TIME)

PREDS(B)   Calculates the road coordinate for equipage B at the particular time (i.e. at TIME)

PST(VEH, T)   Calculates the road coordinate for equipage VEH at time T

VEHBACWITRK(X)   Calculates a reference to an equipage in track x travelling behind

VEHEQUALTRK(X)	Calculates a reference to an equipage alongside in track x
VEHFORWITRK(X)	Calculates a reference to preceding equipage in track x
PLATOONLEADER(VO)	Calculates a reference to a platoonleader for the equipage vo.
ONCOMINGVEHEQUAL ORBACKWITRK(X)	Calculates a reference to an equipage in track x travelling alongside or behind in oncoming traffic stream.
ONCOMINGVEHFORW ITRK(X)	Calculates a reference to preceeding equipage in track x in oncoming traffic stream.
LASTVEHINONCOMING PLATOON(X)	Calculates a reference to last equipage in track x in oncoming traffic stream.
PASSING(X)	Decides whether own head or tail overlaps that of another equipage in track x
STARTPOSSIBILITY	Decides whether start possibility applies. Start possibility if head or tail of own equipage does not overlap that of another equipage in lane 2 or lane 3
CHANGETOTRACK(X)	Move own equipage to track x
BEHINDVEAFFECTED	Decides whether equipage travelling behind in the same lane needs to be reactivated
VEHINTRK1AFFEC	Decides whether equipage in track 1 needs to be reactivated.
REACTFORW	Reactivates preceding equipage
REACTBACKW	Reactivates next equipage travelling behind in the same track.
REACTTRK1VEH	Reactivates the nearest equipage whose tail lies behind the current equipage
CONSTRAINED	Decides whether the current equipage is following
INTERESTING	When an equipage is reactivated the procedure INTERESTING decides whether the equipage is in track 1 or track 2 and is being caught up by another equipage
ACC(SPEED)	Calculates acceleration ability at SPEED

BEABTOFOLR	Decides whether a preceding equipage is "close" and the speed is less than the free blockspeed. "Close" defines the distance between the head of the current equipage and the tail of the preceding equipage as being less than 1.5 times the tail length of the preceding equipage

Routines in conjunction with catching up

CATCHINGUP(X)	Decides whether the current equipage catches up another equipage in track x before passing the next road block limit
VEHOBJCATCHING-UP(VO)	Decides whether equipage VO catches up a preceding equipage before passing the next road block border
CATCHINGUPBEF-PREDICTNEXTEV-TIME(VB)	Decides whether equipage VB catches up the current equipage before VB's PREDICTNEXT-EVTIME

Routines in conjunction with overtaking or passing

MAXSIGHTPNT	Decides whether an overtaking opportunity exists. An overtaking opportunity exists if maximum sight length exists in the road block and the distance between the equipage and the point of maximum sight length is less than 3 m.
RENDEZVOUSQRMAX-SIGHT	
FLYINGOVTAK-ACCEPT	Decides whether an opportunity for overtaking is accepted
ACCOVERTAKING ACCEPTED	Decides whether an opportunity for accelerated overtaking is accepted
ABLE	Decides whether the vehicle has sufficient acceleration ability to carry out an overtaking. More exactly estimated length of the overtaking is less than sightlength x constant

WANT	A random number is drawn and gives "true" with a specified probability. This probability depends on:

1) Accelerated/flying overtaking - OMT

2) Vehicle type and whether a private car is taken into consideration when average speed is less or greater than 20 m/s

3) Road width class - VB

4) Visible/invisible meeting

5) Sight length

VACANT	Decides at point of decision for accelerated or flying overtaking whether it is possible to change track to track 1, i.e. whether track 1 is occupied by another equipage
ALLOW	Decides whether the vehicle is permitted to carry out an overtaking. Permission is given if no overtaking prohibition applies and if no unbroken white line exists. The driver is looking for overtaking restriction min (300, estimated length of the overtaking x constant) m ahead.
TIRED	Decides whether the equipage abandons its attempts at overtaking. The probability of this is at present 0
OBJINSAMETRACK	True if the head of the current equipage overlaps the tail of the preceding equipage in the same track
INITIALPOINTS, LPNT, FINISHPNTS	Decides upon overtaking or passing whether initial points, level points or finishing points apply

direction of travel

level points

current track — Initial points — 3 m — finish points

head length — tail length

tall length equipage object
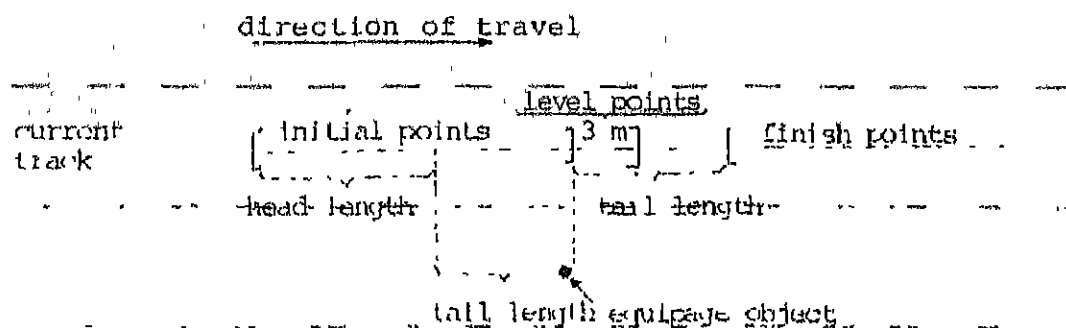
SHORTRETURN   Decides upon overtaking whether short return applies

direction of travel
———————————→

current
track

shortreturn points

tail length
/2

●

equipage object
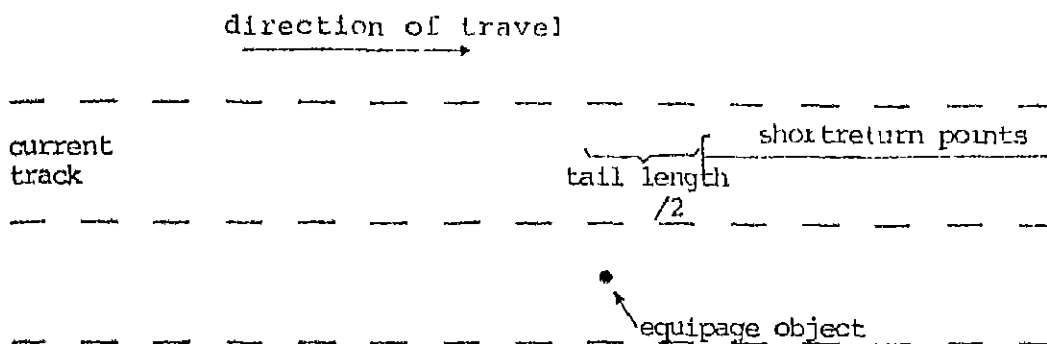
OVERTAKING-
CONTINUE

Decides whether an overtaking is to be completed. Is completed when the equipage has greater speed than the overtaken equipage.

NEWOVERTAKING

Decides whether a new overtaking is likely, implicates that the driver wants to overtake and the vehicle is permitted and has sufficient acceleration ability to carry out an overtaking. Note that this makes NEWOVERTAKING true if no new overtaking is likely.

SCATCHINGUP1

Decides upon completing an overtaking of equipages in a platoon, but not the platoon leader, that the current equipage catches up another equipage in the current track before overtaking is completed.

Routines in conjunction with the equipage being passed

VACANTANDWANT-
TOGOTOTRACK3

Decides when the current equipage is caught up in track 2 whether it can and wants to change track to track 3.

CANRETURN

Decides whether the current equipage in track 3 can return to track 2.

TRAVEL

Apart from the block speed an average slope is assigned to each block. Each equipage also has a power/weight coefficient, P, which determines its ability to reach its block speed, given the particular slope.

The TRAVEL procedure tests this ability by inserting values in the power equation:

$$a = \frac{p}{v} - c_a \cdot v^2 - c_b$$

where

a	= acceleration	m/s^2
p	= power/weight ratio	W/kg
v	= speed	m/s
c_a	= air resistance coefficient	
c_b	= rolling resistance and "slope coefficients"	

In this test v is set to the block speed. If acceleration thereby becomes less than 0 or the current speed is less than the block speed, PTS is inserted in the power equation. Otherwise calculation is made either with the same speed, TS, (time over road stretch) or with a uniform retardation, RETARD, depending on whether the particular speed is equal to or greater than the block speed.

PTS

free block speed

roadcoordinate
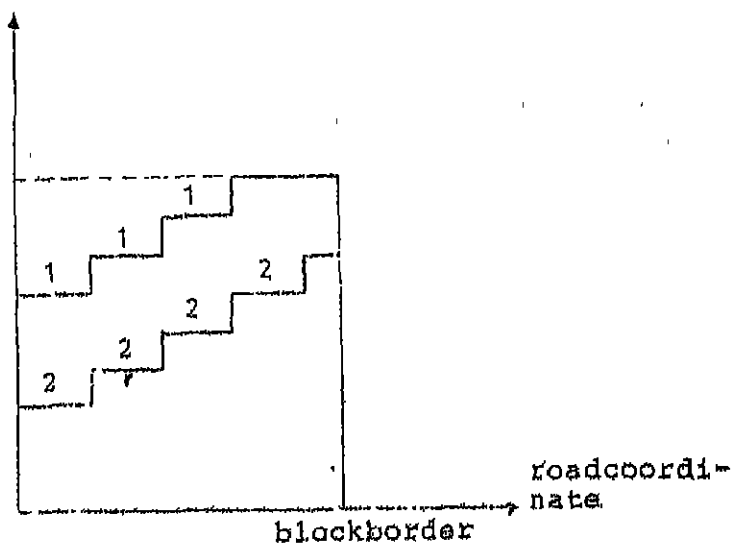
blockborder

In procedure PTS there is a numeric integration of the power equation over time until either the free block speed has been exceeded (case 1 in the figure) or the blockborder exceeded (case 2).

Use is made of

$$a = \frac{dv}{dt} \text{ gives } v_t = v_{t-\Delta t} + \Delta t \cdot a$$

$$v = \frac{ds}{dt} \text{ gives } s_t = s_{t-\Delta t} + \Delta t \cdot 0.5 \cdot (v_t + v_{t-\Delta t})$$

where

a   = acceleration

v   = speed

s   = distance

t   = time

Integration step Δt (DELTA in PTS) is set to

$$\Delta t = k \cdot \text{PRECISION} \cdot |\frac{v_0}{a_0}|$$

where

k   = a constant set to 3

PRECISION = required precision in integration

In the program PRECISION has been set to 0.5 %. v_0 and a_0 are speed and acceleration at the beginning

TIMETOSTART-POSSIBILITY	Calculates time to start possibility.
TIMETOBLOCK-LIMIT(C)	Calculates time to next block limit. *C indicates whether the current equipage is free or constrained.*

Routines in conjunction with catching up

TIMETOCATCHU	Calculates time until the first of the following events: 1) Catching up equipage in track 3 2) Catching up equipage in track 2 3) Block limit
TIMETOCATCHING UPPOINT(X)	If the equipage catches up another equipage in track x the procedure calculates the time to the catching up point.

TIMETOBEHCATCH UPPOINT(C)	Calculates time to the point where the current equipage is caught up. C indicates whether the current equipage is free or constrained.

Routines in conjunction with preparation for following

TIMETOFOLLOW	When an equipage has decided not to carry out a flying overtaking the procedure calculates the time to the point where the equipage has slowed down and travels with a given headway from the preceding equipage.

Routines in conjunction with overtaking or passing

TIMETOOVERTAKACC	Calculates the time to the point for an accelerated overtaking.
TIMETOINITIAL- POINTS(C)	Calculates the time to the point where the overtaking equipage is in level with the overtaken equipage. If the current equipage (overtaking) has a lower average speed than the overtaken equipage the time to the block border is calculated. C indicates whether the current equipage is free or constrained.
TIMETOLPNT(C)	Calculates the time to the point where the overtaking equipage is 3.3 m in front of the overtaking equipage. C indicates whether the current equipage is free or constrained.
TIMETOFINISH- POINT(C)	Calculates the time to the finish point in an overtaking. If the overtaken equipage has a greater average speed than the current equipage the time to the next block border is calculated. C Indicates whether the current equipage is free or constrained.
TIMETOSFINISH- PNT(C)	Calculates the time to a short finish point in an overtaking. A short finish point applies when the current equipage overtakes individual equipages in the platoon with the exception of the platoon leader. C indicates whether the current equipage is free or constrained.

Routine in conjunction with overtaking an equipage

TIMETORETURN- POINT(C)	Calculates the time to a possible point for returning from track 3 to track 1. C indicates whether the current equipage is free or constrained.

APPENDIX - B

FLOW CHART OF PRESENT WORK

START

VRYP=0, VGYP=0
MVNGQVHL=0, VZD=0
FUCYCL=0, VSEMD=0

(2)

1
PREDICT COORD
<=
SIGNAL COORD ?
— N → (V)

Y
2
SIGNAL STATUS ?
GREEN → (G)

RED

R21
IS
THERE VEHICLE IN
FRONT ?
— N → (1)

(R) →

Y

R21
PREDS(FV)
<=
S.COORD - SSD ?
— N → (1)

Y

R211
IS
FV VELOCITY=0 ?
— N → FV.SIGN

R2112
IS
FV.SIGN
→ (V)

Y

R2111
JOIN SIGNAL QUE

(1)

R2111
PREDICT COORD
>=
NOOVRTCOORD ?
— N →

Y

R2
DIST B
<= HD LENGT
- LENGT

Y

```
         ①  ──────►  R212.
                      FSAVEH ?  ──── N ──►  Ⓥ
                         │
                         Y
                         │
                         ▼
                      R2122.
                   PREDICTCOORD          R21221
                        >        ── Y ──► VRYP = VRYP + 1
                   S.COORD - SSD ?                │
                         │                        ▼
                         N                        Ⓥ
  ⌐R¬                    │
  |R|                    ▼
  |E|                  WILL
  |D|                 SIGNAL                HOLD(NEXTSCHANGE)
  ⌐D¬            BECOMES GREEN  ── Y ──►           │
                 BEFORE  REACHING                  ▼
                     SSD ?                         Ⓖ
                         │
                         N
                         │
                         ▼
                       will
                 signal becomes
              green before reaching  ── Y ──►  VSEMD = VSEMD + 1.
                 s.coord with red                   │
                     vel ?                           ▼
                         │                          Ⓥ
                         N
                         │
                         ▼
                      R2121
                  HOLD(upto SSD)
              PREDICTBLBORDERSP=0
             aversp =localsp/2
              JOIN SIGNAL QUE
                         │
                         ▼
                         Ⓥ
```

(G)

G22
IS
SIGNAL QUE
EMPTY ?

G221
FSAVEH ?   N → (V)

Y → (3)

N

G222
FUCYCL = FUCYCL + 1

G222
IS
FV SPEED = 0 ?   N

A62222
PREDS(FV) <=
S COORD - SSD ?   Y

G2222
IS
FV-SIGNAL QUE
LAST ?   N

(V)

Y

Y

N

G2221
PREDICTCOORD
>=
NO OVRT COORD?   N

G22212
dist bet vehls <=
hd length + tailleng(FV) ?   N → (V)

Y

GREEN

G22211
JOIN SIGNAL QUE

G222111
IS
LOCALSP = 0 ?   N →   MVNGQVHL = MVNGQVHL+1   → (V)

Y

localsp = 1·0
predictblbordersp = spred-
blsp.
predblbordertime =
spredblbordertime.
AVB+R>P S(LOCALSP+SPREDBLSP)/2

(V)

V

VTI model modified.

IS LOCALCOORD ≥ DESTINATION? — N → ②

Y

IS simulation time ≥ max. vehgen time or simulation cutoff time? — N → GENERATE NEW VEHICLE ~ → ②

Y

PRINT RESULTS → STOP

FLOWCHART FOR PROGRAMME

APPENDIX - C

LIST OF PROCEDURES ADDED,PROCEDURES CHANGED IN ISRTSM

APPENDIX   C

+ 1)   INTEGER PROCEDURE   system signal(any time)

+ 2)   INTEGER PROCEDURE   myposin sigq(Vb)

+ 3)   REF(Veh) PROCEDURE   vehbackwirrk(X)

+ 4)   REF(Veh) PROCEDURE   vehequalitrk(X)

+ 5)   REF(Veh) PROCEDURE   vehforwitrk(X)

+ 6)   REF(Veh) PROCEDURE   platoonleader(Vo)

+ 7)   REF(Veh) PROCEDURE   oncomingveh equalorbackwitrk

+ 8)   REF(Veh) PROCEDURE   oncomingvehforwitrk(X)

+ 9)   REF(Veh) PROCEDURE   lastvehinoncomingplatoon(X)

+10)   PROCEDURE   reactbackw

+11)   PROCEDURE   ReactforW

+12)   REAL PROCEDURE   headleng(b1,b2)

++13) REAL PROCEDURE   ssd(b)

+14)   BOOLEAN PROCEDURE   behindvehaffected

+15)   BOOLEAN PROCEDURE   beabletfolr

+16)   BOOLEAN PROCEDURE   surprise

+17)   BOOLEAN PROCEDURE   Interesting

+18)   REAL PROCEDURE   oncomvehsightitrk(X)

+19)   PROCEDURE   travel

+20)   PROCEDURE   pts

+21)   PROCEDURE   retard

+22)   PROCEDURE   ts

++23) REAL PROCEDURE   vspredictnextevtime

+24)	REAL PROCEDURE	predtid
+ 25)	REAL PROCEDURE	tidsrot
+ 26)	PROCEDURE	travelconstrained
+27)	PROCEDURE	travel3
+28)	BOOLEAN PROCEDURE	oncomingvehvisible
+29)	BOOLEAN PROCEDURE	rendezvosormaxsight
+30)	BOOLEAN PROCEDURE	drive(c)
+ 31)	BOOLEAN PROCEDURE	scathingup1
+32)	PROCEDURE	ifextralanebeginreactforw
+ 33)	BOOLEAN PROCEDURE	wanttohelpvehbackwtopas
+ 34)	BOOLEAN PROCEDURE	accovertakingaccepted
+ 35)	REAL PROCEDURE	ovtaklength(c,vs)
+ 36)	BOOLEAN PROCEDURE	want(c)
+ 37)	BOOLEAN PROCEDURE	catchingupbefpredictnextevtime(vb)
+38)	REAL PROCEDURE TIME	toreturnpoint
+39)	REAL PROCEDURE	timetocatchingupoint
+40)	REAL PROCEDURE	timetostartposibility
+41)	REAL PROCEDURE	timetomasight
+42)	REAL PROCEDURE	timetorendezvousormaxsight
+43)	REAL PROCEDURE	timetoinitialpoints
+44)	REAL PROCEDURE	timetofollow
+45)	REAL PROCEDURE	timetoblocklimit
+46)	PROCEDURE	write(tex)
+47)	PROCEDURE	wrpost(x)
+48)	PROCEDURE	wrivehdata
++49)	REAL PROCEDURE	saooln

++ 50) REAL PROCEDURE   spredictblbordersp

++ 51) REAL PROCEDURE   spredblbordertime

++ 52) BOOLEAN PROCEDURE   fsaveh

++ 53) BOOLEAN PROCEDURE   posfrontveh

++ 54) REF(Veh) PROCEDURE   frontveh

++ 55) PROCEDURE ACTION SIGNAL

++ 56) PROCEDURE   red

++ 57) PROCEDURE   green

| Indicates changed procedure

+ | Indicates new procedure introduced.

APPENDIX - D

EVENTFILE   DETAILS

APPENDIX   D

EVENT NUMBER	TYPE	DESCRIPTION	WIDTH	STARTING COLUMN
0	I	Event Type	2	
	T	Title	118	

1)   EQUIPAGE ENTERS A STRETCH OF A ROAD

1	I	Eventtype	2	1
	I	IDNU	5	3
	I	DIRNU	3	8
	I	ORIGIN	6	11
	I	LOCALCOORD	6	17
	I	DEST	6	23
	I	VEHICLETYPE	3	29
	R	BDS(VON)	6	32
	R	P(P/W)	6	38
	R	TIME+TIMESHIFT (ARRIVAL TIME)	10	44
	R	LOCALSP	8	54

2)   EQUIPAGE LEAVES A STRETCH OF A ROAD

2	I	Eventtype		
	I	IDNU	5	3
	R	LOCALCOORD	7	8
	R	AVERSP	8	15
	I	OWNTRACK	3	33
	R	TIME+TIMESHIFT (DEPARTURE)	8	36

3) <u>PASSING MEASURING POINT</u>

3	I	Eventtype	2	1
	I	IDNU	5	3
	R	LOCALCOORD	7	8
	R	AVERSP	8	15
	R	LOCALTIME	10	23
	I	OWNTRACK	3	33
	T OR I	Front Vehicle Identification	7	36
	I	VF IDNU	5	43
	I	VB IDNU	5	48
	R	Energy Consumption	7	53

4) <u>DIRECT OVERTAKING STRTED</u>

4	I	Eventtype	2	1
	I	IDNU	5	3
	R	LOCALCOORD	7	8
	P	AVERSP	8	15
	R	LOCALTIME	10	23
	T	OWNTRACK	3	33
	I	TYPE	3	36
	I	VF.IDNU	5	39
	I	VF.TYPE	3	44
	R	VF.AVERSP	8	47
	R	SIGHTLENGTH	7	55
	R	ONCOMVEHSIGHT-ITRK	7	62
	R	ONCOMVEHFORWI-TRK	8	69
	T		4	73

7) PASSAGE POINT

7	I	Eventtype	2	1
	I	IDNU	5	3
	R	LOCALCOORD	7	8
	R	AVERSP	8	15
	R	LOCALTIME	10	23
	I	OWNTRACK	3	33
	I	TYPE	3	36
	I	VF.IDNU	5	39
	I	VF.TYPE	3	44
	I	VF.AVERSP	8	47

8) PASSAGE COMPLETED

8	I	Eventtype	2	1
	I	IDNU	5	3
	R	LOCALCOORD	7	8
	R	AVERSP	8	15
	R	LOCALTIME	10	23
	I	OWNTRACK	3	33

9) TRACK CHANGE

9	I	Eventtype	2	1
	I	IDNU	5	3
	R	LOCALCOORD	7	8
	R	AVERSP	8	15
	R	LOCALTIME + TIMESHIFT	10	23
	I	OWNTRACK	3	33
	I	NEWTRACKNO	3	36

10) <u>FOLLOWING STARTED</u>

	10	I	Eventtype	2	1
		I	IDNU	5	3
		R	LOCALCOORD	7	8
		R	AVERSP	8	15
		R	LOCALTIME	10	23
		I	OWNTRACK	3	33

11) <u>OPPORTUNITY TO DIRECT OVERTAKING NOT ACCEPTED</u>

	11	I	Eventtype	2	1
		I	IDNU	5	3
		R	LOCALCOORD	7	8
		R	AVERSP	8	15
		R	LOCALTIME	10	23
		I	OWNTRACK	3	33
		I	TYPE	3	36
		I	VF.IDNU	5	39
		I	VF.AVERSP	8	47
		I	SIGHTLENGTH	7	55
		R	Distance to Oncoming Vehicle intrack2	7	62
		R	ONCOMINGVEH. AVERSP	8	69
		T		4	

12) <u>OPPORTUNITY TO ACCELERATED OVERTAKING NOT ACCEPTED</u>

12	I	Eventtype	2	1
	I	IDNU	5	3
	R	LOCALCOORD	7	8
	R	AVERSP	8	15
	R	LOCALTIME	10	23
	I	OWNTRACK	3	33
	I	TYPE	3	36
	I	VF.INDU	5	39
	I	VF.TYPE	3	44
	R	VF.AVERSP	8	47
	R	SIGHT	7	55
	R	Distance to oncoming vehicle	7	62
	R	Oncomingveh.aversp	8	69
	T		4	

13) <u>BLOCKBORDER PASSAGE</u>

13	I	Eventtype	2	1
	l	IDNU	5	3
	R	LOCALCOORD	7	8
	R	AVERSP	8	15
	R	LOCALTIME	10	23
	I	OWNTRACK	3	33
	R	BDS(VON)	6	36
	I	VEHTYPE	2	42
	R	P(P/W)	6	44
	R	Energy Consumption(W)	7	70

14) EVERY CHANGE

14	T	Eventtype	2	1
	I	IDNU	5	3
T OR I		VF.INDU	5	8
	I	OWNTRACK	2	13
	T	F if following	2	15
	T	B if behind catching	1	17
	R	LOCALCOORD	6	18
	R	LOCALSP	6	24
	R	AVERSP	6	30
	R	PREDBLBORDERSP	6	36
	R	LOCALTIME	8	42
	R	PREDICTNEXTEVTIME	8	50
	R	PREDBLBORDERTIME	8	66
	T		1	74
	T	TEXT	19	75
	R	LOCALCOORD	6	94
	R	LOCALSP	6	100
	R	AVERSP	6	106
	R	PRE	6	112
	R	PREDBLBORDERTIME	7	118

15) OVERTAKING INTRUPPTED BEFORE LEVEL POINT

15	I	Eventtype	2	1
	I	IDNU	5	3
	R	LOCALCOORD	7	8
	R	AVERSP	8	15
	R	LOCALTIME	10	23
	I	OWNTRACK	3	33

16) <u>OVERTAKING FINISHED AFTER LEVEL POINT</u>

16	I	Eventtype	2	1
	I	IDNU	5	3
	R	LOCALCOORD	7	8
	R	AVERSP	8	15
	R	LOCALTIME	10	23
	I	OWNTRACK	3	33

17) <u>FOLLOWING TERMINATED</u>

17	I	Eventtype	2	1
	I	IDNU	5	3
	R	LOCALCOORD	7	8
	R	AVERSP	8	15
	R	LOCALTIME	10	23
	I	OWNTRACK	3	33

18) <u>OVERTAKING LEVEL POINT</u>

18	I	Eventtype	2	1
	I	IDNU	2	1
	I	LOCALCOORD	5	3
	R	AVERSP	8	15
	R	LOCALTIME	10	23
	I	OWNTRACK	3	33
	I	TYPE	2	36
	T or I	VB.IDNU	5	38

R	VB.AVERSP	8	38
I	PREDS(VB)	7	43
R	VB.AVERSP	8	50
I	VB.TYPE	2	58
I	INCOMINGVEH.I D	5	60
I	PREDSCONCOMINGVEH	7	65
R	ONCOMINGVEH.AVERSP	8	72
I	ONCOMINGVEH.TYPE	2	80
I	ONVF.IDNU	5	82
I	PREDS(ONVF)	7	87
R	ONVF.AVERSP	8	94
I	ONVF.TYPE	2	102

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